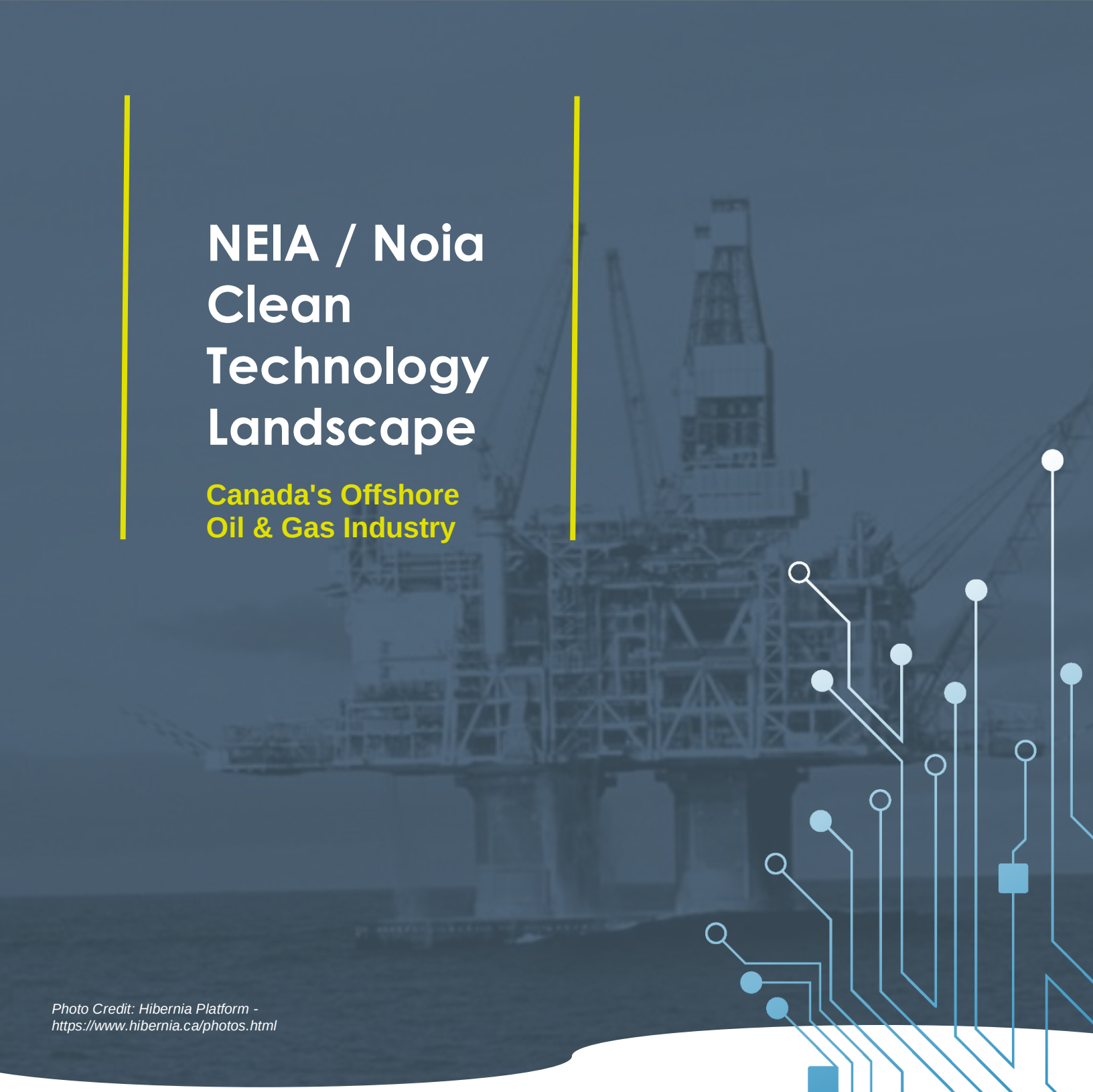
NEIA / Noia Clean Technology Landscape

Canada's Offshore Oil & Gas Industry



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Abbreviations

ACOA	Atlantic Canada Opportunities Agency
AI	Artificial Intelligence
AOSL	Autonomous Ocean System Laboratory
APEC	Atlantic Provinces Economic Council
APM	Asset Performance Management
ASV	Air Supported Vessel
AUV	Autonomous Underwater Vehicle
BDC	Business Development Bank of Canada
CAPP	Canadian Association of Petroleum Producers
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilization and Storage
CFREF	Canada First Research Excellence Fund
CIC	Canadian Institute of Cyber Security
CNA	The College of the North Atlantic
CNER	Centre for Nuclear Energy Research
CNLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
COVE	Centre for Ocean Ventures & Entrepreneurship
CRIOP	Crisis Intervention and Operability analysis
DER	Distributed Energy Resources
DNA	Deoxyribonucleic Acid
DOC	Digital Offshore Canada
DOT	Dartmouth Ocean Technology
E&P	Exploration and Production
E&T	Education and Training
ECRC	Eastern Canada Response Corporation
EDC	Export Development Corporation
EEM	Environmental Effects Monitoring
EOR	Enhanced Oil Recovery
EPC	Engineer, Procure and Construct
EV	Electric Vehicle
FPSO	Floating production storage and offloading
FRB	Fast Rescue Boat
GBS	Gravity Based Structure
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
HERF	Harsh Environment Research Facility
HMDC	Hibernia Management and Development Company
HR	Human Resource
HVDC	High Voltage Direct Current
IBDF	Innovation and Business Development Fund
IMR	Inspection, Maintenance and Repair
ISED	Innovation, Science and Economic Development Canada
IOSS	Ice Ocean Sentinel System
LNG	Liquified Natural Gas
LPG	Liquefied Petroleum Gas
MCE	Memorial Centre for Entrepreneurship
MEA	Maritimes Energy Association
MI	Marine Institute
MIRA	Norwegian Method for Environmental Risk Analysis
MR	Marine Renewables
MRI	Magnetic resonance imaging
MUN	Memorial University of Newfoundland
N/A	Not Applicable
NATI	Newfoundland and Labrador Association of Technology and Innovation (current name is TechNL

NB	New Brunswick
NEIA	Newfoundland and Labrador Environmental Industry Association
NL	Newfoundland and Labrador
NMR	Nuclear Magnetic Resonance
Noia	The Newfoundland and Labrador Oil and Gas Industries Association
NRCan	Natural Resources Canada
NRC-IRAP	National Research Council – Industrial Research Assistance Program
NRPOP	Northern Region Persistent Organic Pollution Control Laboratory
NSERC	Natural Science and Engineering Research Council of Canada
OEM	Original Equipment Manufacturer
OERA	Offshore Energy Research Association
OFI	Ocean Frontier Institute
OFS	Oil Filtration Solutions
OSC	Ocean Supercluster
OSCAR	Method of Oil Drift Modelling
PEI	Prince Edward Island
PIRAM	Pipeline Ice Risk Assessment and Mitigation
POB	Personnel on Board
PRNL	Petroleum Research Newfoundland and Labrador
QA	Quality Assurance
R&D	Research and Development
RDC	R&D Corporations of NL
ROV/ROUV	Remotely operated underwater vehicle
RPAS	Remotely Piloted Aircraft System
SBTi	Science based targets initiative
SDTC	Sustainable Development Technology Corporation
SGIN	Smart Grid Innovation Network
SINTEF	Norwegian independent research organization
SME	Subject Matter Expert
SMR	Small Modular Reactor
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCM	Technology Centre Mongstad
TDGP	Total Dissolved Gas Pressure
UAV	Unmanned aerial vehicle
UNB	University of New Brunswick
US	United States
USC	Unmanned Surface Craft
VC	Venture Capitalist
VOC	Volatile Organic Compounds

01
Executive Summary

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1. Executive Summary

This study provides an assessment of clean technology, or cleantech research and development capabilities and activities in Atlantic Canada as they apply to Canada's offshore oil and gas industry. Through focused surveys, interviews and market research, key stakeholders were evaluated for their corporate and R&D focus in climate change, sustainability, and environmental performance.

Stakeholders were grouped as follows:

1	Oil & Gas Companies and supporting Tier-1 Contractors
2	Innovation Support Ecosystem
3	Private Sector Entities

Challenges were identified and mapped with the capabilities and activities of the regional cleantech ecosystem. From this process, strengths were identified, and recommendations made for future activities.

Drivers of Change

Drivers of change at the global and local level actively define the challenges faced by the oil and gas operators. The challenges faced is trending increasingly towards improved environmental performance. These include:

- Federal and Provincial Climate Change Policy
- Environmental, Health and Safety Standards
- Corporate Climate Change Strategy
- Technology Advancement, Efficiency & Waste Reduction
- Local Market Drivers specific to Atlantic Canada

Offshore Sector Challenges

When surveying the Oil & Gas Companies, and Tier-1 contractors operating in the sector, both sets of stakeholders expressed similar challenges for the industry. These were summarized into eight specific challenges:

1	Environmental Sensing, Monitoring and Characterization
2	Production Efficiency Optimization
3	Gas Turbine Emissions Reduction and Machinery Electrification
4	Flaring Reduction and Recovery
5	Hazardous Offshore Discharges and Disposal
6	Oil Spill Emergency Response
7	Logistics Optimization
8	Remote and Integrated Operations

Innovation Support Ecosystem

The innovation support ecosystem that supports cleantech development in the offshore oil and gas industry comprise:

- Post-Secondary Institutions
- Incubator Organizations
- R&D Facilitators
- Government Funding Agencies

Interviews were conducted with key representatives from organizations within each category to identify relevant capabilities and activities.

Cleantech Ecosystem

Private businesses engaged in cleantech development in Atlantic Canada are varied by size, sector focus, and product or services offerings. Using related keywords, a web-based sector mapping was deployed to create a list of candidate companies to approach for a business survey of their engagements in the offshore industry.

Through both the web search and surveys, a list of cleantech activities prominent in the region were identified and a view was developed of business motivations driving involvement in the cleantech industry servicing the offshore oil and gas operators.

Key findings from the study in terms of the roles of the different business groups in addressing the challenges are:

- All operators are engaged in cleantech innovations to some degree. GHG reduction through process efficiency optimisation, renewable energy sources and remote operations (when economical) are common themes among the oil and gas companies, with both corporate level activities, and local awareness and engagement.
- Tier-1 contractors have a full suite of corporate level products and services which could potentially address many of the challenges.
- Post-secondary institutions offer undergraduate and graduate degree courses, some with direct application in providing solutions to address these challenges. The various specialized labs and facilities at these institutions, such as the Harsh Environment Research Facility (HERF) and Enhanced Oil Recovery (EOR) lab at Memorial University are well equipped to carry out innovative research in cleantech.
- Private local businesses already engaged in cleantech innovation tend to be working in the fields of remote sensing, environmental characterization and oil spill detection with robotics and subsea drones. Other notable areas where cleantech innovations occur are in the fields of logistics and oil spill response.

Conclusions

Each of the offshore sector challenges was mapped against existing capabilities and activities across the Tier-1 contractors, private sector businesses and post-secondary institutions. Observations from this section were summarized in a SWOT analysis, leading to the following conclusions:

1. There is a strong ecosystem when it comes to addressing the challenge of **environmental sensing/monitoring and characterization, oil spill response, logistics optimization and remote operation.** This is not surprising as these challenges require local knowledge and are, therefore, well-suited to businesses where there is local presence.

2. In the challenge area **of production efficiency optimization**, system-wide knowledge of production assets is key to providing such services and relevant knowledge generally resides within Tier-1 contractors. Digitalization will play a key role in solving this challenge and there exists capabilities to support it within the region; however, there is potential for demand in the industry to outstrip capacity.

3. In the challenge area **of gas turbine emissions reduction** where proprietary technology is often used, efficiency optimization efforts are typically referred to the OEM, managed through Tier-1 contractors. Emission reduction is also often achieved through system-wide operational efficiency to reduce energy consumption. This undertaking resides mostly with Tier-1 contractors who have asset-wide knowledge.

   Emissions reduction through carbon capture and sequestration (CCS) technology appears to be under-represented regionally although significant research on CO_2-EOR has been carried by MUN. Significant capability in the region can also be found with respect to electrification from shore, ranging from Tier-1 multi-disciplinary project capability for offshore cable installations as well as regional private companies experience in electrical grid distribution from hydropower.

4. In the challenge area of **flaring reduction and recovery**, a system-wide understanding is required, thus the involvement of Tier-1 contractors. There are therefore very few private sector companies which have capability in this area. Currently, there is very little post-secondary research in this area and no evidence of ecosystem wide collaboration was observed.

5. In the challenge area of **hazardous offshore discharge disposal**, there are a handful of water treatment companies in the private sectors with capability along with some post-secondary activity. No evidence of ecosystem wide collaboration is observed.

6. One area that potentially could play a role in the future is the development of a hydrogen based economy. This topic appears to be under-represented with respect to activities and capabilities within the region.

Recommendations

Significant strengths were identified in the area of environmental monitoring including sensing, autonomous robotic vehicles and operating in harsh environments. We suggest further supporting these capabilities to reinforce a centre of global excellence. An important example of work that is currently underway is the projects supported by the Ocean Supercluster.

Recent oil spill events reinforce the importance of a robust capability in the area of monitoring, sensing and characterization to aid mitigation and emergency response. **Given the emerging developments to improve these capabilities, we recommend continuing support of and encouraging collaboration across the ecosystem**.

We recommend continuing to stimulate private sector involvement in the digitalization of the offshore and reinforce ties with the post-secondary institutions and Tier-1 suppliers in order to build further capacity and meet the growing demand. Notably, the growing high-tech industry in the region speaks to the significant capabilities available to the offshore industry.

Solutions encompass remote operations for reduced Personnel on Board (POB), digital twinning for improved operational efficiency and robotic automation for remote inspection and maintenance activities. The operational efficiencies driven by these solutions lead to improved environmental performance with digitalization as an enabler.

Alongside the existing and ever-growing regional strengths in environmental monitoring, sensing and autonomous platforms, **continued support for digitalization should help to grow the region's capacity to better respond to the net zero commitments of operators and governments**.

A significant source of CO_2 emission involves both the transportation of materials and personnel to and from the offshore production and drilling platforms as well as the transportation of crude oil from production site to shore. **There are potential opportunities to improve these logistics through even more integrated coordination, digitalization of operations and hybridization of propulsion systems**. Capability exists in the region in all aspects; however, continued support and coordination would improve the environmental performance of these activities.

The current power supply on the offshore platforms fueled by natural gas represents about 70% of total GHG emissions making this one of the most important challenges to solve. Solutions have been proposed, including electrification from shore, integration of local renewables and carbon capture and sequestration from post-combustion emissions. **A comprehensive options study is recommended to determine a viable path forward. This may also consider potential pathways for monetization of the produced natural gas.**

Advocate for regulatory alignment and economic incentive to ensure best available technology is adopted for key environmental impact activities such as drill cutting disposal and produced water. For example, advanced drilling lubricants exist that are less impactful on the environment, but which are not used due to cost.

02
Cleantech Scope & Drivers

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2. Cleantech Scope & Drivers

2.1 What is Cleantech?

Cleantech can be defined as any technology which has direct or indirect positive impact on environmental performance such as emissions reduction, sustainability of resources and energy use, risk mitigation and environmental characterization and monitoring, whether commercially available or under on-going research and development.

For the purpose of defining the context of this work, cleantech activities within the offshore oil and gas industry is categorized into four broad themes, namely:

Reduction of GHG Emissions	Includes technologies relating to GHG emissions reduction, such as flare reduction, carbon capture for offshore oil and gas installations, use of carbon/carbon dioxide, etc.
Clean Energy & Energy Efficiency	Includes renewable and alternative energy related technology (e.g. wind, tidal, solar, energy storage, Small Modular Reactor, etc.) as well as technologies that improve offshore oil and gas operational efficiency and equipment availability.
Environmental Impact Performance & Sustainability	Includes technologies that monitor environmental impact from offshore oil and gas activities (e.g. wastewater and produced water disposal, drill cuttings treatment and disposal, ecological impacts and pollution monitoring) with the aim to improve and reduce negative environmental impacts and improve sustainability of operations.
Environmental Characterization and Monitoring	Includes ocean environment related characterization and mapping such as on seabed, genomics, iceberg, sea states, biodiversity, etc.

Each of the above themes consists of a number of keywords that identify more specific activities within each category. *Figure 2-1* shows some of the keywords used. A full list of keywords used to identify with each category can be found in Appendix 1.

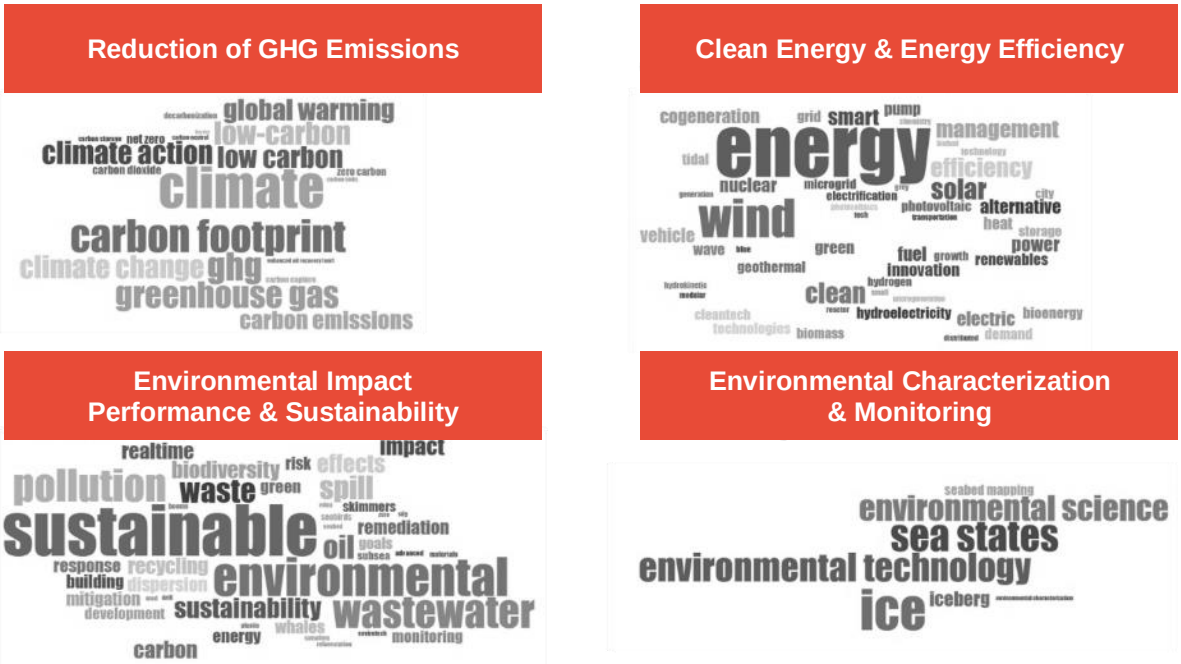


Figure 2-1: Keywords for Four Broad Cleantech Themes

2.2 What are the Drivers of Change in the Sector?

Growth in unconventional oil production coupled with advances in low emissions technologies (e.g. electrification of transportation) have combined to change public perception of global oil supply scarcity. These trends, along with a greater urgency for climate action, has put pressure on oil operators to play a role in reducing the sector's carbon footprint and positively contribute to the climate agenda.

While efforts to curtail the use of fossil fuels increase, the global energy demand is still expected to rely substantially on oil and gas for decades to come[11]. As such, reducing the environmental impact of its production-related activities remains crucial.

Externalities such as government policy, public opinion and energy alternatives (renewable and technological advancement) as well as factors such as sustainability of investment and operational cost-saving alongside corporate reputational motivations and commitment to social responsibility are further accelerating the drive for change in the industry. The key ones are listed and described in the following sections.

2.2.1 Nationally Determined Climate Change Target

Canada, under the Paris Agreement[1], committed to reduce its GHG emissions by 30% below 2005 levels by 2030. Like all regions, Atlantic Canada and its offshore industry, will be required to contribute to Canada's overall reduction effort. When set alongside the sector's aspiration to increase production, such commitments cannot be met without significant reduction in both GHG intensity (i.e., through efficiency), and absolute GHG reductions (for example, through alternative power supply).

In addition to the Paris Agreement, Canada has also endorsed the World Bank's "Zero Routine Flaring by 2030" initiative[2], and is implementing legal, regulatory, investment and operating environment changes to meet this goal.

2.2.2 Federal and Provincial Climate Change Policies

A key government policy driver intended to induce clean technology innovation is carbon pricing. In line with the federal carbon pricing, NL has introduced a carbon price of $20 per tonne of GHG on combusted fossil fuels across the economy from January 1, 2019, rising $10 per tonne each year to $50 in 2022. This is expected to continue to increase as the federal government has recently indicated a carbon tax target of $170 per tonne of GHG by 2030[8].

However, for both onshore and offshore large industrial facilities emitting more than 25,000 tonnes of GHG emissions annually, a performance standard system has also been put in place. Each NL offshore facility easily falls under this framework and will be required to reduce GHG emissions by 8% in 2020, 10% in 2021 and 12% in 2022 below its 2016 to 2018 average emissions-to-output ratio. The GHG reduction target compliance may be achieved through three forms of credits established in the Management of Greenhouse Gas Act[7], namely a fund credit (carbon tax), performance credit (for over-achieving GHG reduction target) and a provincial offset credit system which is still under development.

2.2.3 Environmental Standards

In addition to climate change-related policy, environmental standards across the offshore oil and gas supply chain are being tightened - from overboard discharges to the ocean during exploration and production to impurities in crude oil sales and refinery products. Stricter standards have pushed the sector to implement advances in monitoring and reporting to ensure compliance and penalty where appropriate.

Offshore Waste Treatment Guidelines[3] set standards and recommended practices with regards to disposal at sea for offshore oil and gas activities in Canada. The guidelines also set out the identification, monitoring and reporting of discharges. The performance target for average residual oil in water for produced water overboard discharge of 30 mg/L is aligned with the recommendation from OSPAR[4], a standard commonly used for the North Sea offshore discharges. The performance standard on average “synthetic-oil-on-cuttings” is 6.9 g/ 100 g oil on wet solids which is much higher than the required 1% of oil in cuttings before disposal overboard recommended by OSPAR[6]. As an increasing number of exploration drillings straddle the border of Canadian and international water, it is likely that current Canadian guidelines will be aligned to the more stringent OSPAR standards in the future.

2.2.4 Health and Safety Standards

Health and safety is a core value in every process and operation of the oil and gas industry. Such standards and best practices are continually reviewed across the industry to promote safe and responsible development of energy sources through rigorous hazard identification, prevention, mitigation and risk reduction. The drive towards continual improvement in Health and Safety standards can be accelerated through cleantech innovation.

Hazard prevention may simply mean reduction or removal of human presence in a hazardous environment. Reduction of site presence through more automation and remote operation not only improves health and safety performance but also provide improved environmental performance through reduced transportation between sites.

Mitigation of escalating hazards such as oil spill intervention has also been greatly improved through the use of virtual training simulators to improve response, preparedness and efficiency. Such innovation reduces the need for direct human intervention and associated risk with “live” emergency responses exercises.

When hazards like icebergs are out of human control, the industry has worked towards reducing the risk through better monitoring of the surrounding environment and intervention only when necessary.

2.2.5 *Corporate Climate Change Strategy*

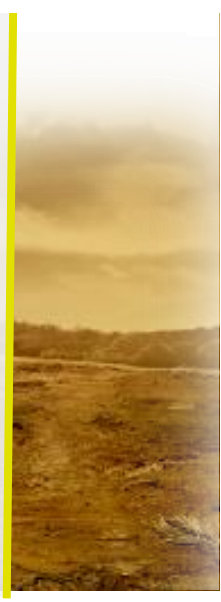
Various reporting obligations and pressures are motivating companies and organizations, including the oil and gas sector, to better assess and manage climate-related risks and opportunities. These trends include wider adoption of the recommendations of the *Task Force on Climate-Related Financial Disclosures*[9], which is now supported by over 1600 companies and organizations. As a result, greater attention to governance, strategy, risk assessment and management, and metrics and targets are driving increased demand for cleantech, especially in the energy intensive industries. For the oil and gas sector, examples of transition risks and opportunities – that is risks and opportunities associated with a transition to a low-carbon economy – include the following:

Transition Risks

- **Policy and Legal:** Increasingly strict regulation of existing products and services
- **Technology:** Risks in adopting emerging technologies such as electrification or hydrogen technologies
- **Market:** Lower demand and prices for fossil fuels
- **Reputation:** Public and investor stigmatization carbon intensive industries

Transition Opportunities

- **Resource Efficiency:** Improving energy efficiency of operations
- **Energy Source:** Shift to renewable power sources
- **Products and Services:** Development of low emissions products
- **Markets**: Access to capital for low-carbon investments



As a whole, corporate climate change strategy promotes adoption of cleantech in the offshore oil and gas sector for reduction of GHG emissions, energy efficiency, and clean energy.

2.2.6 *Technological Advancement*

The oil and gas sector has been at the forefront of technological development targeting increased production and cost saving. With the 2008 financial crisis, the 2014 oil price crash and the recent global economic crisis brought about by COVID-19, reduced economic activities and reduced oil prices are leading oil and gas companies to rely further on technology to reduce extraction cost. In addition to the availability of technological advancement in oil and gas processing, such as better solvents for impurities extraction, external technologies, such as remote electrification from shore, have also gained traction (e.g. Johann Sverdrup in Norway). The life cycle of technology innovation, from research to commercialization, has also shortened as a result of faster computing processing power and the adoption of digitalization

2.2.7 *Operational Efficiency & Waste Reduction*

Operational cost savings associated with operational efficiency and waste reduction have long been a driver of change in the oil and gas sector. Optimization of fuel consumption for power generation and motive forces per unit production is a frequent target area for operational efficiency and, as a result, lower fuel-burning emissions. Improving operational reliability by optimizing equipment sparing on a high footprint offshore real estate, implementing predictive maintenance strategy and real time monitoring reduces downtime-associated flaring events. Digitalization, through parallel process simulations with digital twins, has also enabled the sector to further improve efficiency and reduce waste.

2.2.8 Canadian Offshore Drivers

There are aspects specific to Atlantic Canada's offshore that are influencing change in the oil and gas sector. These include:

- The Ocean environment, home to a diverse and vulnerable Marine Ecosystem which is vital for the survival of fish stocks, migratory birds, marine mammals and seat turtles.
- Indigenous people whose livelihood depends on the ocean ecosystem.
- The presence of ocean sea ice and icebergs which pose a scouring hazard to subsea infrastructure (subsea well heads, pipelines, etc.) and direct impact/collision on surface stationery (GBS, FPSO, future floating wind farms, etc.) and moving assets (marine vessels).
- Abundance of hydro electric generation onshore available in the region.

2.3 Geography of Interest

Atlantic Canada's main offshore oil and gas production is located offshore Nova Scotia (NS) and Newfoundland & Labrador (NL). Offshore production in NS has ceased since the shutdown of Sable and Deep Panuke in 2018 and there has been no exploration drilling since. NL currently has four operating assets in its offshore jurisdiction:

- two fixed platforms: Hibernia GBS and Hebron GBS; and
- two floating production facilities, Sea Rose and Terra Nova FPSO.

Under the Atlantic Accord in 1985, NL offshore activities are required for "…economic growth and development in order to optimize benefits accruing to Newfoundland [and Labrador] in particular and to Canada as a whole…". The accord dictates that a Benefit Plan is required before any work is carried out in the offshore area. The Benefit plans among others, maximizes the local content, training and employment of local workforce, the use of local business' products and services as well as contributes towards the province R&D activities. Over the years, due to the accord, some of the prominent socio-economic benefits impacts[10] are:

- Contribution of up to 25% of the provincial GDP
- Direct and indirect employment of over 5,000 and 14,600 respectively
- Capital spending of $2.3 Billion
- Over $500 million in R&D, education and training since 2004
- $19.8 billion in cumulative royalties since 2017

The growth potential is also immense with over 20 offshore basins mapped, but only two actively explored and only 7% of the potential leads and prospects licensed. The NL offshore is approximately 1.5 times the size of US Gulf of Mexico. An estimated 37.5 billion barrels of oil and 133.6 trillion cubic feet of natural gas were identified in the two active exploration areas of West Orphan and Flemish Pass regions[10].

The benefits and potentials above show how important it is to leverage and grow capabilities and capacities of the local industries to support targeted offshore activities such as cleantech innovation, development, and deployment. At the same time, Atlantic Canada also needs to maintain a competitive business environment in order o attract further cleantech investment.

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Atlantic Canada's Offshore Landscape

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3. Atlantic Canada's Offshore Landscape

3.1 Sector Overview

3.1.1 Oil & Gas Companies

Oil & gas companies who are actively involved in Exploration and Production (E&P) activities in Atlantic Canada were surveyed to determine the following:

Photo Credit: The Bay du Nord FPSO - https://www.equinor.com/en/where-we-are/canada-bay-du-nord.html

- General view of the most urgent cleantech related challenges within E&P
- Existing top 5 clean projects currently ongoing in Atlantic Canada and corresponding level of R&D investment
- Key drivers for cleantech spending in Atlantic Canada.

The methodology used is set out in Appendix A.1. This section summarizes the aggregated findings of the survey with the oil & gas companies that responded.

All operators were consistent in declaring GHG emission reduction as the top challenge they need cleantech to address. The extent of the reduction varied between meeting the performance-based NL GHG reduction imposed by the government and a more stringent net zero corporate commitment.

In meeting the GHG reduction requirements, the focus areas vary among the different operators but generally converge on reduction through:

- Energy Efficiency improvement and Production Optimization
- Electrification and use of renewables (wind, etc.) for platform power and transportation
- Improvement in availability of compression train(s) through improved reliability
- The implementation of flare recovery
- The implementation of carbon capture
- Advanced ocean environmental characterization and monitoring

For most operators and their partners alike, retrofitting post combustion carbon capture onto major emitting sources onto offshore the facilities (e.g. power generation and compression trains) remains prohibitively complex and uneconomical. Most operators are more supportive of the recent studies on supplying electricity from shore and offshore renewables (e.g. floating wind) and understanding the challenge of such infrastructure in an iceberg environment. Based on the feedback, activities such as optimization of energy usage and improved reliability were common. This perhaps suggest the focus on GHG reduction by operators in the region is more incremental as the bolder reduction options are complex and uneconomical at current market environment.

Some specific themes of ongoing projects within the cleantech space are:

- Process optimization of power generation
- Process optimization of water injection
- Logistics optimization
- Environmental characterization using subsea drones and digital twins
- Fuel switching from diesel to cleaner alternatives
- Real time emission monitoring as KPIs to improve operational efficiency
- Flare and Cargo Tank VOC recovery

Key drivers for cleantech spending by oil and gas companies currently engaged in E&P in Atlantic Canada are shown in Figure 3-1. The results show the following:

- Social responsibility is unanimous as the driver for cleantech;
- Access to funding is an important enabler as most either voted “Very Important” or “Neutral”;
- Financial viability or economic viability also scores favourably with up to 50%;
- Regulatory framework support has mixed responses as some see it as barrier while others think it is very important; and
- Technology Access locally is relatively even with operators willing to engage with global technology if not available in Atlantic Canada.

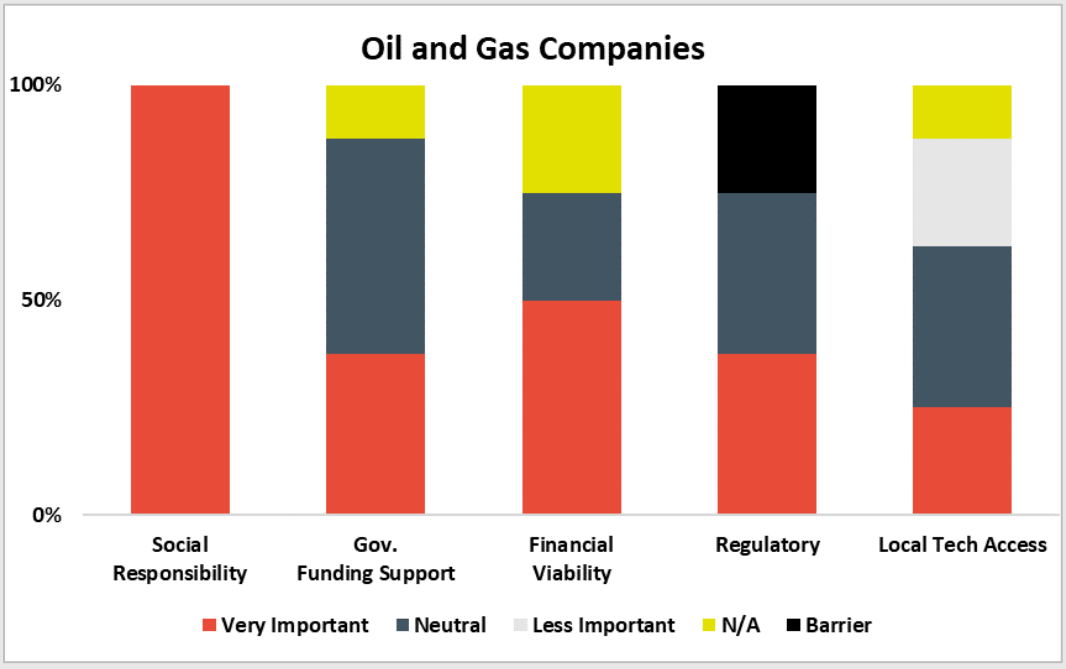


Figure 3-1: Key drivers for Cleantech Spending by Oil and Gas Companies in Atlantic Canada

3.1.2 Tier-1 Contractors

Multi-national Tier-1 contractors who have a presence in Atlantic Canada were surveyed in accordance with the methodology set out in Appendix A.1 for the following:

- General view of the most urgent cleantech related challenges within E&P
- Primary cleantech products and services offered for the offshore oil and gas in the Atlantic Canada
- Current top 5 clean projects in Atlantic Canada and corresponding company's revenue spent on cleantech of R&D in the region
- Key drivers for cleantech engagement in the Atlantic Canada

Like many oil and gas operators, a number of Tier-1 contractors have set corporate sustainability targets based on emission reduction, clean energy/renewables and energy efficiency. Many in this group also viewed meeting those corporate targets as the most urgent challenge.

Highlights of relevant corporate-wide cleantech products and services are detailed in Table 3-1. Regionally in Atlantic Canada, products and services offered depends on demand. Some of those recent engagements in cleantech in Atlantic Canada are highlighted in **bold.**

Most products and services in which most Tier-1 contractors have both the capabilities and capacities can be broadly categorized into:

- **System-wide solutions**: Digitalization/Digital Twin, logistic optimization, energy efficiency and remote operation.
- **High risk and/or high upfront investment**: CCS, energy storage, hydrogen
- **Industrial renewables with infrastructure scope**: Floating Wind, Electrification (inc. smart grid system).

Some of the more unique products and services are in the form of tidal/wave energy, hull coatings, geothermal, biofuels and hybrid/renewable propulsion systems for marine vessels,

Many Tier-1 contractors indicated a reluctance to participate in government funded programs as the funding requirement tends to restrict the profitability. As a result, many often fund a cleantech project themselves if there is demand without strings attached. Halliburton Lab and Lloyd's Register Foundations are two examples of Tier-1 contractors' initiative in stimulating innovations outside the government funding by supporting start-ups directly on projects deemed to be in demand or have potential to meet future needs.

Tier-1 contractors' investment in cleantech innovation within Atlantic Canada is typically low although some Tier-1 contractors have indicated up to 5-10% of revenue is invested in cleantech globally.

Key drivers for cleantech spending by oil & gas companies currently engaged in E&P in Atlantic Canada are shown in Figure 3-2. The results show the following:

- **Demand**: All Tier-1 contractors agreed that customer demand in this case, that of oil and gas operators is most important.
- **Social responsibility**: Social responsibility is 2nd highest.
- Both **financial viability** and **access to government funding** are over 50% in "Most Important" category with almost 25% of Tier-1 contractors didn't think government funding as relevant. To most Tier-1 contractors, projects funded through government sources means substantial reduction in standard market rates which is often undesirable.
- **Regulatory framework** support has mixed responses. Regulatory framework may drive or impede the oil and gas operators' response to cleantech engagement and that in turn drives the Tier-1 contractor response. It is therefore not surprising that Tier-1 contractors' response to the regulatory driver mirrors those from oil and gas operators.
- **Local access to clean technology** was the lowest priority indicating that the best available technology globally will be sought for cleantech if not available locally. This is in line with the feedback from the oil and gas operator on same question.

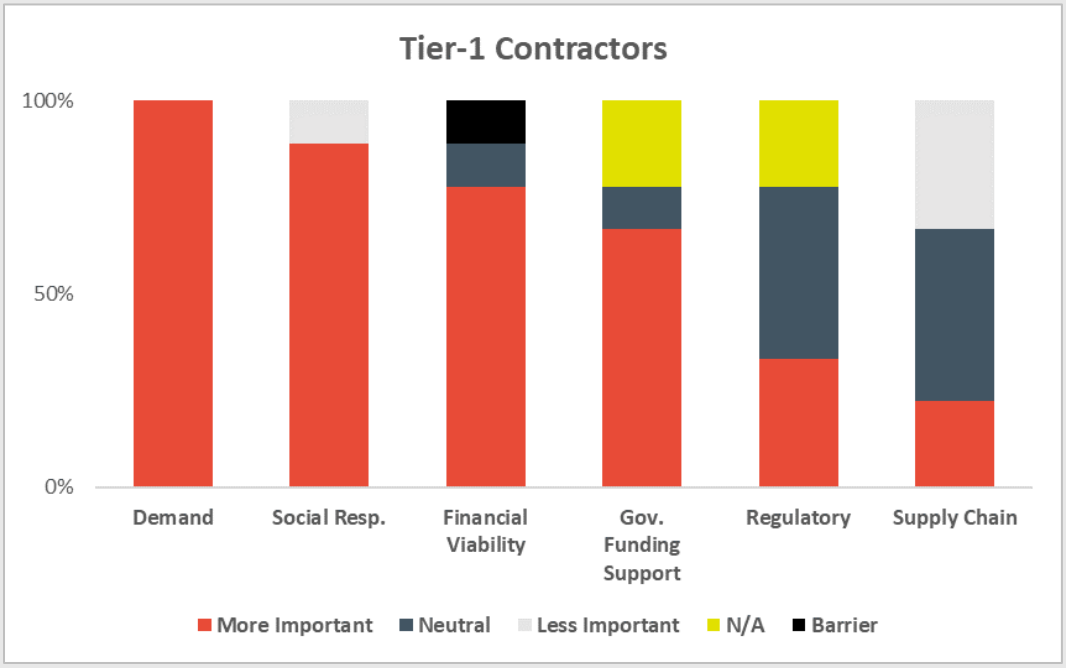


Figure 3-2: Key Drivers for Cleantech Engagement for Tier-1 Contractors in Atlantic Canada

Table 3-1: Summary Table of Major Tier-1 Contractors Corporate-wide Cleantech Engagement

No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada
1.	**Aker Solutions**	
		• Growing low carbon solution business aimed at GHG reduction, Clean Energy and Energy Efficiency. • 20/25/30: Derive 20% and 25% of revenue from renewables and low carbon solutions respectively by 2030. • **In Atlantic Canada, recently engaged in offshore electrification from shore through recent NEIA/Noia study and investment in digitalization**. • Globally, Aker offers renewable energy (Floating wind farm) and Low Carbon Solutions (CCUS: Aker Carbon Capture: Just Catch™, Offshore Just Catch™, Big Catch, Mobile Test, CO_2 for EOR, Subsea Gas Compression, power distribution and Electrification from shore). • Other related GHG reduction initiatives are in operational logistics aimed at reduced personnel via remote operation and digitalization: – Subsea intervention and remote workover riser (e.g. riserLOCK™) – Digitalization/technology around logistics, document and people management to improve work and energy efficiency. – ix3™ - a software and digital services company to accelerate field development projects and optimize asset performance. – Unmanned FPSO Concept.
2.	**DNVGL**	
		• Risk Management and Consulting form with some NL based team working on Offshore Wind Projects for the USA. • **Cleantech products and services in Atlantic Canada is mainly risk management, such as Offshore Wind and Carbon Capture Risk Management.** • Globally, some of the initiatives in cleantech space are: – Industry-first recommended practice on QA of oil and gas industry's digital twin with TechnipFMC – Remote surveys/inspection of offshore cranes – CCS partnership with TCM, SINTEF – Oil Spill Risk Assessment and response planning in accordance with Norwegian Standard (MIRA) and using leading oil drift model (OSCAR)

No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada
3.	**Halliburton**	
		• Plan to submit emission reduction targets in 2021 grounded in Science Based Targets Initiative (SBTi) and in alignment with Paris Agreement. • Plan to roll out sustainability label in 2021 detailing carbon footprint of every products/services • **Cleantech products and services in Atlantic Canada:** – **Baroid Separation Solution: Offshore on-site drill cuttings and wastewater treatment to reduce oil residual content suitable for overboard disposal.** – **On-site treatment and overboard disposal saves site to shore transportation cost and associated carbon footprint.** – **Cleaner drilling oil but customer's decision is often driven by cost and hence has not been successful.** • Other notable product globally: Digital Well Operations connecting rig site workers to remote operation centres where a digital twin of the well sits. • **Halliburton Labs** (https://www.halliburtonlabs.com/) was launched in mid 2020 to help start-ups to grow cleaner energy initiatives with world-class scaling capabilities. Key areas of interests are: – Clean Energy Generation – Transmission/Distribution – Energy Storage – Energy Conservation • Circular Economy
4.	**Hatch**	
		• Corporate target of net-zero in operations by 2030 while helping clients be responsible stewards of the resources that people need and want to improve their lives, and that society needs for a sustainable future while helping them shift their product mix to a more sustainable one. • Consulting Services, Technology Commercialization of cleantech. • Hatch HxO: Scheduling and Logistics Optimization tool to allow cost saving and fuel usage optimization to improve environmental performance. • Not specifically in Atlantic Canada, but Hatch is investing in the areas of fusion energy, Small Modular Reactors, waste to low-carbon fuels and hydrogen, hydropower technologies, carbon capture, hybrid renewable power systems, energy storage, grid modernization, robotics and automation, digital twins and other technologies relevant to our clients across Canada and globally.

No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada
5.	**INTECSEA**	
		• Offshore wind to displace on-board power generation. • Working with wind development proponents in the areas of offshore site characterization, geotechnical/geophysical surveys, power transmission, floating and subsea substations.
6.	**Lloyd's Register**	
		• **Cleantech products and services in Atlantic Canada** – **Review and on-board verification of the hazardous material onboard oil and gas installation during decommissioning (e.g. Deep Panuke decommissioning process)** – **Anti-fouling hull coating with real time monitoring to understand the impact of coating on fuel efficiency and emissions** • Globally, notable project relating to cleantech is Digital Twin with Bluewater to monitor hull integrity at different FPSO positioning based on similar work with Navy in order to optimize positioning and reduce maintenance cost. • Involve in Poseidon Principle assess future risk of vessels not meeting emissions standards. • **Top five projects with high TRL:** 1. **Maritime Decarbonization Hub** 2. **Digital Twin (With OSC)** – Aim to reduce fuel consumption for Navy and brand visibility for environmentally-conscious customers 3. **Hull Coating –** Drag-reducing coating to save fuel 4. **Wind Power-assist Flettner Rotor Propulsion** 5. **Sensor Tech –** Distributed Sensor to detect emission • Investment also in CRIOP by funding a post-doc position. • Lloyd's Register Foundation (https://www.lrfoundation.org.uk/en/) – Global charity supporting research, innovation, and education to make the world a safer place, focusing among others, on Safety at sea, of digital systems, for a sustainable future, of food and physical infrastructure.

No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada
7.	**SNC-Lavalin**	

- Corporate Target: Improvement initiatives between 2020 and 2025:
  - Goal 7: Affordable and clean energy,
  - Goal 11: Sustainable Cities and Communities
  - Goal 13: Climate Action
- Globally, some of the engagement in cleantech space are:
  - Wind farms (over 375+ offshore inc. floating, 55+ onshore)
  - Tidal and wave energy
  - Geothermal topside technology and engineering configuration
- Local investment spends ranges between 10% and 25%
- R&D for cleantech is focused on digital strategies and technology such as:
  - Battery storage, peak lopping, localized energy sources and hub networks to integrate with alternative energy sources
  - a holistic approach to power generation and reduction in emissions
  - remote monitoring of tools, digital twins, and real time operational controls of facilities to reduce in emissions and improve production operations
  - Facility optimisation with autonomous vehicles (e.g. drone) inspections to reduce carbon intensive remediation activities.
- Other capabilities: Geospatial, GIS, geomatics survey with CIRRUSinsite™

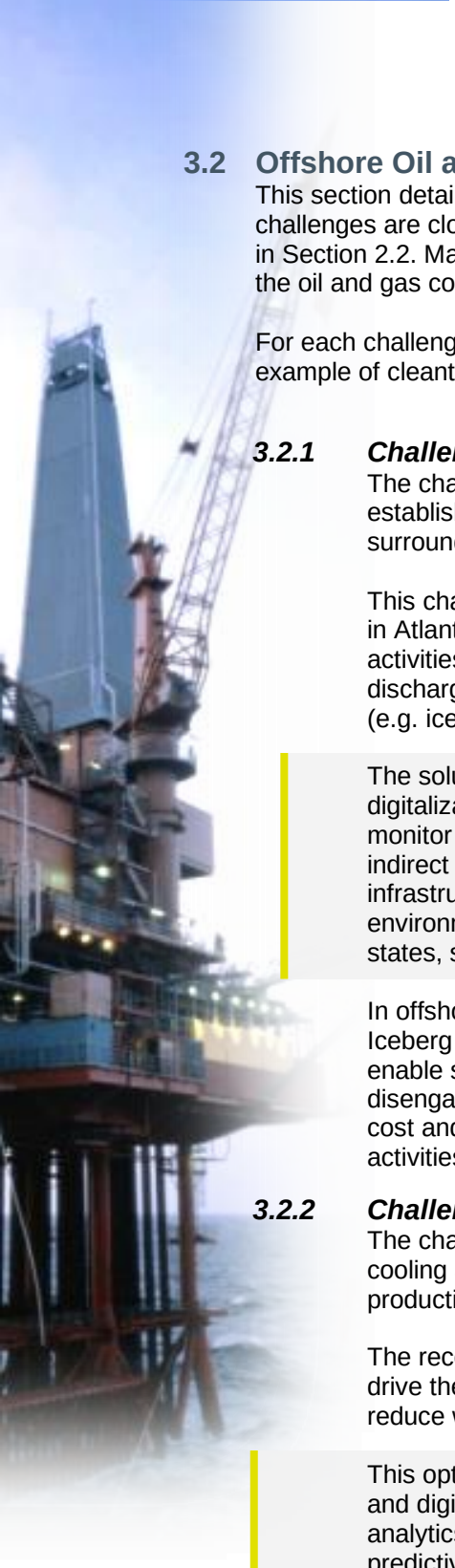
No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada

8. TechnipFMC

- Corporate Target: 50 by 30: 50% GHG reduction in Scope 1/2 by 2030 (Reference to 2017 baseline).
- Globally, cleantech products and services offered are:
  - Carbon-advantaged solutions
    - iProduction™ - Integrated ecosystem to streamline operations and reduce equipment footprint, GHG emissions, cost
    - Subsea 2.0 – Smaller, lighter and fewer parts to reduce complexity , optimize installation and reduce emissions from material transport.
    - Blue Hydrogen / CCUS
    - iLOF™ for condition-based maintenance
    - Subsea Robotics and ROV : Gemini with improved and increased tooling, remote movement resistance to provide feedback to pilot, improved stabilisation
  - Lower Carbon, Carbon-free opportunities
    - Green Hydrogen with McPhy
    - Offshore Floating Wind
    - Tidal/wave Energy
    - Biofuels
    - All-electric subsea field, renewables powered.
- Other cleantech activities:
  - Subsea Integrated Maintenance and Repair (IMR)
  - Installation of batteries in construction vessels - hybrid vessels (Deep Arctic Jan 2021 with battery installation) *
  - Biofuel in vessel (working with operators on biofuels type to make it competitively priced)
  - Plastic pollution prevention - zero pollution from ships to sea from plastics e.g. water bottles now replaced with multi-use bottle, Recycling of Synthetic fibre rope
  - Deep Purple™ - combined offshore wind power and green hydrogen subsea production and storage and transport pressurized green hydrogen, deliver hydrogen to consumers at sea or export via pipeline
- Iceberg impact simulation, Ice-MAS
- Local investment is limited
- Elsewhere CCS is the focus in UK (Acorn CCS)
- Other relevant services: Digitalisation and cyber security
- Long term initiatives at corporate level are
  - Hydrogen using renewable resources (wind/wave energy for electrolysis),
  - CCS pilot project, and
  - Subsea Energy Storage for renewables

No	Tier-1 Companies	Primary products and services relating to cleantech for the offshore oil and gas globally and in Atlantic Canada
9.	**Wood**	

- Corporate Target: 40% GHG reduction in Scope 1/2 by 2030.
- Cleantech products and services in Atlantic Canada:
  - ENVision - Software for baseline of greenhouse gas emissions for companies to track emission reduction initiatives
  - Environmental, Metocean Characterization, Environmental Effects Monitoring (EEM) services for offshore.
  - Environmental impact assessment.
  - Virtuoso®: Operational Logistics Optimization, Asset Performance Management and performance surveillance tool
  - From Energy Transition Standpoint,
- Wind/Solar/renewables
- Carbon Capture, Waste to Energy, Hydrogen
- Grid and Microgrid technology
- Energy Storage, battery
- Sustainable infrastructure (smart city)
- Real time monitoring and analytics to provide decision making support for logistics, POB reduction for further afield development.



3.2 Offshore Oil and Gas Sector Challenges

This section details eight key challenges faced by the offshore oil and gas industries. The challenges are closely linked to the global and regional drivers of change in the sector as described in Section 2.2. Many of these challenges were also in alignment with this study's engagement with the oil and gas companies and the Tier-1 contractors.

For each challenge, the key driver(s), potential solutions to address the challenge and specific example of cleantech innovation relevant to the challenge are described at high level.

3.2.1 Challenge 1: Environmental Sensing, Monitoring and Characterization

The challenge is to characterize the key ocean environment elements in order to establish a baseline environment state and to continue monitoring the impact of surrounding offshore activities.

This challenge is driven primarily by the unique and sensitive ocean environment offshore in Atlantic Canada thus the need to minimize environmental impacts from offshore activities (marine vessel transportation, seismic activities, drilling and production discharges) and the need to reduce the hazardous risks of environmental phenomenon (e.g. iceberg, waves, etc.) impact on offshore activities and assets.

The solution covers the use of modern technology such as advanced sensors, digitalization, drones (subsea, surface and air), robotics and satellite to survey and monitor the ocean environment above and below sea level which may have direct or indirect impact on offshore stationary (e.g. offshore platform, subsea pipeline and infrastructure, etc.) and mobile assets (e.g. marine vessel transportation). The ocean environment in this context includes, but is not limited to, metocean conditions (sea states, seabed temperature etc.), marine biological systems and iceberg geolocation.

In offshore NL, iceberg scouring and impact on offshore assets is often a concern. Iceberg management with real-time tracking using satellite and risk-based assessment enable safe and timely intervention (such as iceberg towing or pipeline flushing and disengagement) where appropriate. Tackling such challenge has the potential to reduce cost and ensure safe operation of offshore activities by de-risking impact of offshore activities on environment and vice versa.

3.2.2 Challenge 2: Production Efficiency Optimization

The challenge is to optimize the usage of key utilities such as chemicals, fuel required for cooling and heating as well as for power generation aboard the platform per unit of production.

The recent demand destruction of oil and continued price volatility drive in recent years drive the urgency of such utility usage savings through deeper process optimization to reduce waste and cost.

This optimization can be achieved through digital optimization with data analytics and digital twinning as the centrepiece of production efficiency indicator. Such analytics are also used to optimize production over a life cycle of the asset with predictive maintenance recommending frequency and type of maintenance required.

The ultimate prize will come from production efficiency optimization where interaction with the environment could also be digitally modelled and linked with process simulations to monitor and improve environmental performance without production loss.

3.2.3 Challenge 3: Gas Turbine Emissions Reduction

The challenge is to reduce emissions from fossil-fuel powered turbines at offshore oil and gas installations.

During normal production, natural gas is produced as part of the oil extraction process. A portion of the natural gas (about 10%) is combusted to power gas turbines for both electricity generation and to directly drive rotating machinery such as the compression trains. Most of the gas is compressed and reinjected back into the reservoir for pressure support. The natural gas is readily available readily as an energy source as long as there is continuous production. Diesel backup generation for safety-critical equipment and instrumentations will kick-in during unplanned and emergency shutdowns. The use of natural gas as fuel source has been challenged due to GHG emissions from this fossil-fuel combustion. Internal corporate drivers such as social responsibility commitments to meet GHG targets and external drivers such as carbon tax imposed by governments across the world have created this cleantech challenge.

The benefits of such a reduction are significant as combustion of fuel for power generation offshore contributes typically to more than 50% of the total GHG emitted per installation. As a result, the two target focus areas in relation to emission reduction mentioned by operators are improving fuel consumption efficiency and/or switching to a direct electrification from sustainable renewable sources such as hydro, wind or tidal. Carbon capture and sequestration has also been mentioned as a potential emission reduction solution allowing the continued use of fossil-fuels as a low-carbon energy source, by absorbing the CO_2 produced and reinjecting it into depleted reservoirs for storage or enhanced oil recovery (EOR).

Potential solutions to this challenge include:

- Electrification over long distance subsea cable transmission and connectors (subsea and riser).
- Integration of offshore renewables such as wind and tidal along with energy storage.
- Carbon Capture and Sequestration. Considering the limited footprint on offshore installations, modularization of equipment for carbon capture system would be required.

A key consideration for any change to the power generation system is the impact on the gas compression system.

3.2.4 Challenge 4: Flaring Reduction and Recovery

The challenge is to reduce and/or eliminate planned operation and production flaring from offshore oil and gas installations.

This is driven by the climate change commitment enforced through the NL Management of Greenhouse Gas Act[7] and also the drive towards “Zero Routine Flaring by 2030” to eliminate production flaring by 2030.

Operational and production flaring typically makes up to 15% of the total GHG emission per installation. Optimization of planned maintenance events and controlled start-ups and shutdowns minimize the frequency of such events and thereby minimizing the gas flared. Production flaring can also be minimized with better automatic control systems and maintenance of leaking valves.

> The solution to eliminate production flaring typically involves flare recovery system technology by re-routing the gas from the flare header back into the compression train. This is a proven process with commercial scale examples of its application, but it is often only implemented with suitable government regulatory drivers such as carbon tax or zero flaring policy.

With zero flaring, it is important to consider the disposal of the excess gas which would otherwise go to flare. As all offshore oil and gas installations in NL re-inject most of the gas, additional gas routed back to compression trains may create a bottleneck on the gas processing and in turn reduce oil production.

With the above in consideration, unless governments provide the appropriate economic incentive to eliminate flaring, investment in flare recovery system is unlikely to be financially attractive to stakeholders. It is not surprising that only a handful of operators indicate zero flaring as a focus area.

The survey also found that most operators cited flaring reduction in the context of the need to improve reliability and availability of key equipment such as compression trains in order to avoid unplanned operational flaring. Predictive maintenance enabled through digitalization and analytics are often the least costly option with the most impact when improving equipment uptime.

3.2.5 Challenge 5: Hazardous Offshore Discharges and Disposal (Cuttings, Process Water, etc.)

The challenge is to treat hazardous and contaminated by-products from offshore activities before discharging them overboard from marine vessels (supply, transportation, installation, etc.) and production/drilling platforms.

The requirement for treatment is driven first and foremost by social responsibility towards the environment ensuring no hazardous pollutants are discharging into the environment. Environmental standards set by government ensure a uniform baseline and best practices are implemented in this area.

> This solution includes the adoption of new technology to improve treatment of hazardous and contaminated by-products. The by-products in this context include, but are not limited to, drilling muds, cuttings and produced water. Produced water is often treated to a high standard for re-injection into the reservoir as EOR. Depending on the availability of a depleted reservoir, treated drill cuttings can also be reinjected into the formation.

New technology is constantly being developed by Original Equipment Manufacturers (OEM's) to improve treatment processes. The complexity often lies on the feasibility of retrofitting existing installations with newer equipment. The use of cleaner and more environmentally friendly oil for drilling process may also provide a partial solution to the challenge.

3.2.6 Challenge 6: Oil Spill Emergency Response

The challenge is to provide an effective oil spill detection, mitigation and efficient intervention with minimum risk.

This challenge is driven primarily by social responsibility towards the environment and its ecosystem. In some oil spill cases, the impact on the environment also severely impacts the livelihood of surrounding communities.

> The solution typically covers the detection using novel technology such as radar and mitigation such as using advanced dispersants. Virtual reality simulator training for oil spill events can provide safe and realistic training for relevant personnel to ensure efficient emergency response with the minimum risk.

3.2.7 *Challenge 7: Logistics Optimization*

The challenge is to reduce emissions by managing transportation (such as marine, helicopter) with optimization of scheduling, transport (design, type and size), fuel type used and personnel/cargo load.

This challenge is driven by the need to reduce waste in fuel usage through both improving the efficiency of the vessels/vehicles and the overall logistics efficiency, thus. reducing emissions.

Some of the key elements of this challenge requiring consideration are:

- Complex logistics data analytics and optimization routines
- Integrated scheduling and tracking
- Innovation in alternative and greener energy sources to power both marine vessels and helicopters, ranging from natural gas to batteries
- Maximization of cargo loading and personnel seating to reduce travel frequency and optimize fuel usage per unit load
- Innovation in ship hull design and advanced drag-reducing coatings
- Innovation in propulsion systems

3.2.8 *Challenge 8: Remote and Integrated Operations*

The challenge is to reduce the requirement for continual personnel presence at operating site offshore with greater automation and establishment of reliable process monitoring and control centres at a safe, remote locations.

This is driven by the need to reduce transportation emissions and also the drive for lower site POB. Reduction of personnel on board also improves safety performance with fewer people exposed to risk offshore as well as overall economic benefits.

Digitalization and subsea data connection cables are key elements to implement remote/integrated operations with the potential of remote collaborative troubleshooting where necessary. Advancement in robotics starts to play a significant role in providing remote inspection and maintenance at locations deemed difficult and too dangerous for personnel to access.

04
Innovation Support Ecosystem

NEIA / Noia Clean Technology Landscape

HATCH

4. Innovation Support Ecosystem

This section of the report sets out an overview of the enabling support available to help the oil and gas sector respond to drivers of change and resolve the challenges set out above.

4.1 Overview of Landscape

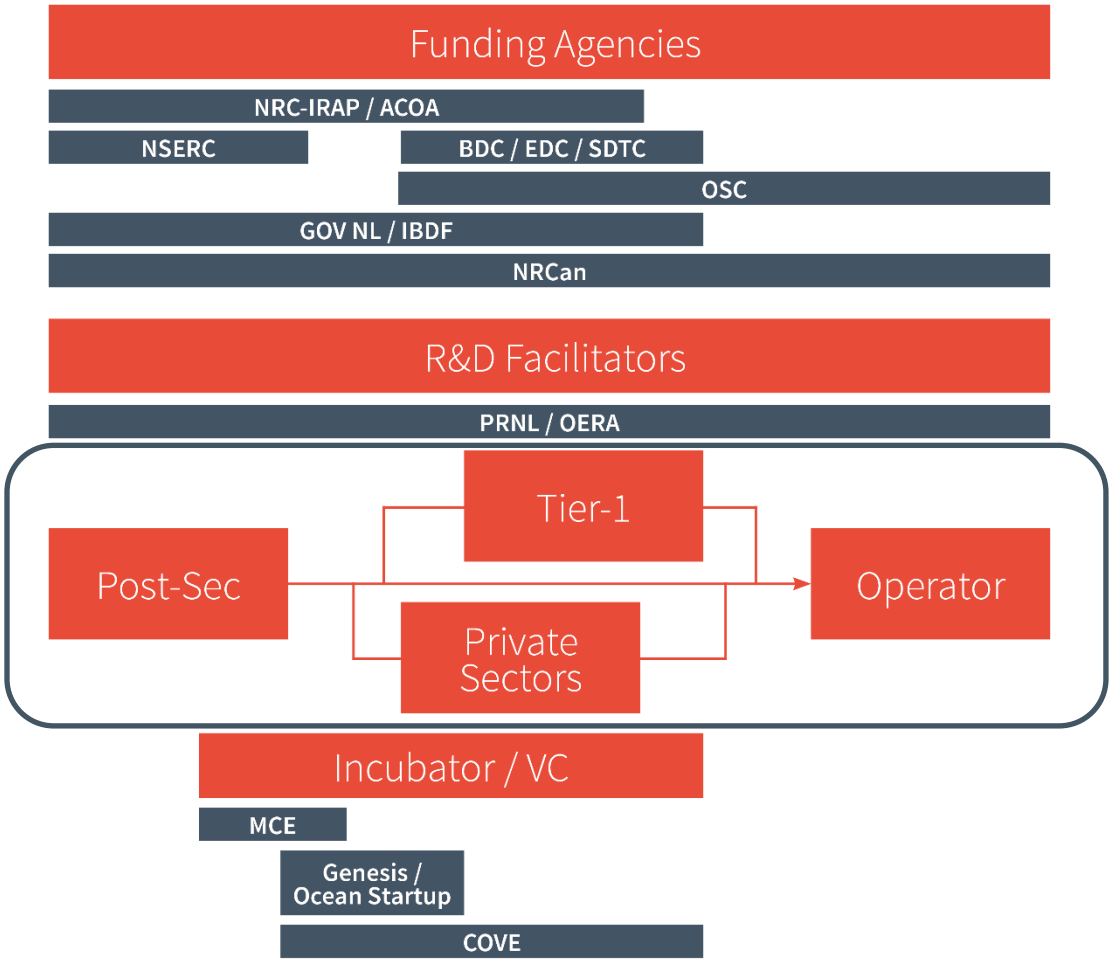


Figure 4-1: Atlantic Canada Innovation Ecosystem

The innovation pathway for cleantech solutions is varied but relies heavily on a robust ecosystem of organizations to support the fostering of ideas through to development and ultimately to commercialization (see Figure 4-1). Post secondary institutions perform the research necessary to develop new solutions as well as training the essential workforce of the future. These technologies may be commercialized by existing companies or form the foundations of new companies. At all stages, development is supported by government funding agencies to support the evolving needs of society as a whole and the regulations and incentives that reflect these. Crucial to solving these challenges is investment from the private sector. In the case of the offshore operators, a portion of their R&D investment is channelled through organizations who facilitate development of solutions to common challenges. Finally, incubators and accelerators support entrepreneurs in developing new companies required to commercialize solutions, providing connections to funding from private and public sources.

4.2 Post-Secondary Institutions

Universities and Colleges play a vital role in the innovation ecosystem by:

- Training the future workforce
- Conducting pre-commercial research and feeding the innovation funnel
- Providing an opportunity for industrial partners to leverage their research investments

The key capacities and activities were determined through interviews with research department heads at each institution and through information collected from their respective websites.

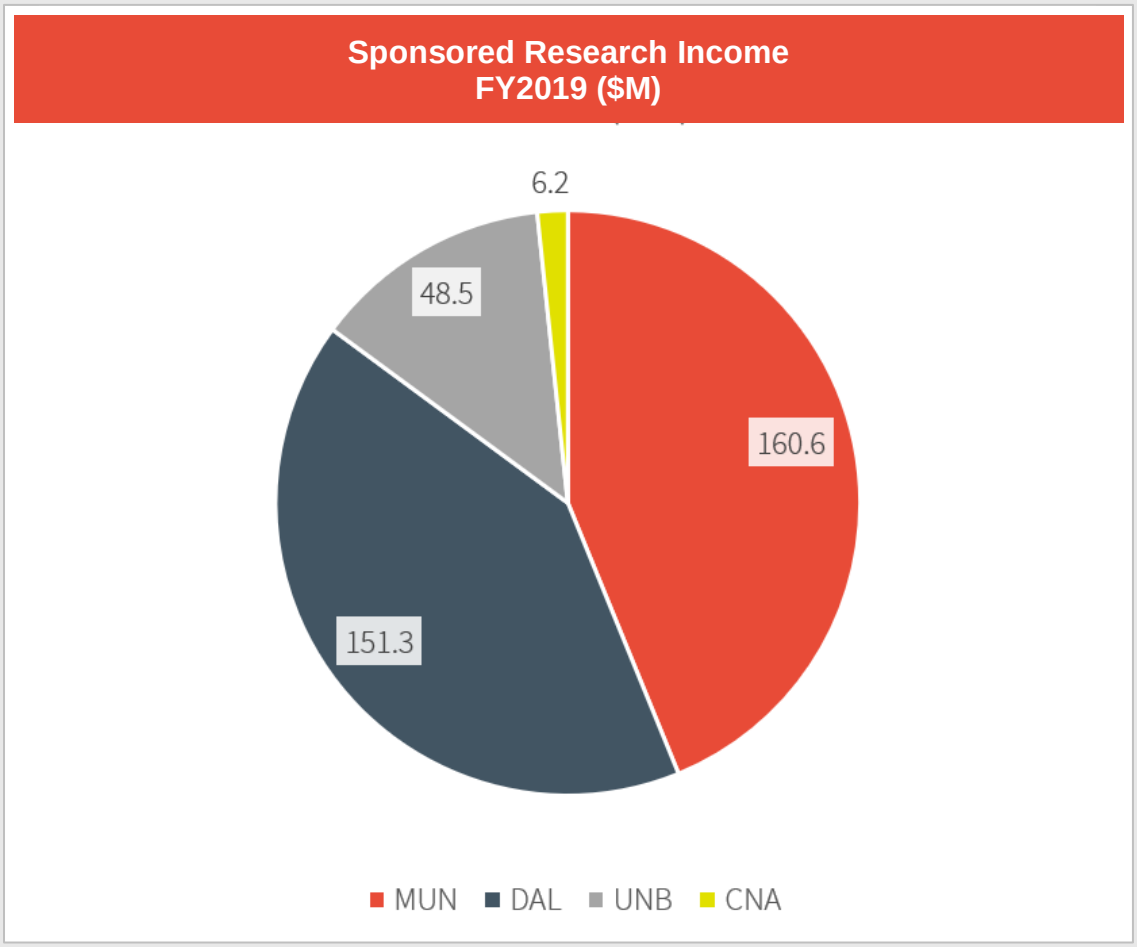


Figure 4-2: Post-Secondary Research Income[5]

4.2.1 Memorial University

As the only university in Newfoundland and Labrador, much of its work is focused on the ocean economy and it has strong ties to the offshore oil and gas industry. In 2019, between 30-35% (350-425) of Engineering student work terms were related to the oil and gas sector. More than 40% of the Marine Institute's marine and ocean technology graduates find permanent employment in the sector.

As one of the top 20 research universities in Canada, MUN's research income was $138M in 2019/20 and 40% of its research is ocean related. Strategic Research Themes include Environment, Energy and Natural Resources; Governance and Public Policy; Information and Communication Technology; and Oceans, Fisheries and Aquaculture. Enrolment at MUN includes 19,000 undergraduates, 1,500 graduate fellowships and 854 PhD students. Unique ocean related programs include the only co-op program in Ocean and Naval Architectural Engineering in the world and Canada's only ROV Operator Program[12].

Key Facilities and Areas of Research:

- **Harsh Environment Research Facility (HERF)**
  - In August 2019, Husky Energy invested $1M, along with $2.7M from ACOA and $2.4M from GovNL, $3.2M from MUN and $6.7M from the Canada Foundation for Innovation. into the creation of HERF. The facility includes a multi-purpose testing facility to simulate harsh ocean conditions with icebergs and sea ice, high winds, waves, sea water spray, fog and other harsh climactic conditions for testing systems and structures in conditions specific to the region. It is led by Dr. Yuri Muzychka, head of the Department of Mechanical Engineering.
- **Autonomous Ocean System Laboratory (AOSL)**
  - Founded in 2010 by Dr. Ralf Bachmayer, Professor of Engineering, Dr. Brad DeYoung, Professor of Physical Oceanography, Department of Physics and Physical Oceanography.
  - The goal of the AOSL is the development and proof of performance of systems in cold ocean environments for ultimate commercialization. Unmanned systems include Autonomous Underwater Vehicles, (AUVs) Unmanned Surface Craft (USC) and Unmanned Aerial Vehicles (UAVs) for iceberg surveying.
  - Partners include Suncor, GovNL, and ACOA
  - Facilities include:
    - 150m2 mechatronics development lab in MUN's Carew Engineering Building.
    - 68m2 workspace in the SUNCOR offshore R&D centre
    - 200m2 assembly facility
    - Facilities of the Marine Institute Holyrood Marine Base – R&D workspaces, large and small research support vessels and deep cold water test range.
  - Projects include:
    - Ice Ocean Sentinel System (IOSS) – a suite of technologies to enable comprehensive ocean environment observation and data collection in iceberg invested waters (AUV, USC, 3D mapping,
    - Electrical and vehicle management systems,
    - Short Range Radar
    - Wave energy conversion and advanced propulsion system for vehicles.
- **Northern Region Persistent Organic Pollution Control Laboratory (NRPOP LAB)** – led by Bing Chen – Department Head of Civil Engineering, Director NRPOP Lab and NSERC PEOPLE CREATE Network - the NRPOP LAB is recognized worldwide for its pioneering research on persistent and toxic organic pollutants, such as oils and pesticides, and mitigation and recovery in cold regions and harsh marine environments.

- **Ocean Engineering Research Centre** – With a $2M investment, Suncor helped to expand MUN's Carew Building with a 1,320 m2 extension of research space. It includes the NSERC CREATE Training Program for Offshore Technology Research led by Professor Wei Qiu who specializes in solving fluid -structure interactions, specifically looking at the interaction of vessels and structures with ice. Brian Veitch – NSERC/Husky Energy Industrial Research Chair in Safety at Sea – is working on safer work environments, focused on both work and environmental safety, with a goal to eliminate incidents of human error such as spills, lost time injuries and optimize time, profit and environmental performance.
- **Hibernia Enhanced Oil Recovery Laboratory** – Established with investments of $1.64M from R&D Corp. of NL (RDC) and $13.5M from HMDC and led by Professor Lesley James, the lab provides laboratory and simulation support to the EOR activities of the local oil and gas industry, solving the fundamental problems of multiphase flow.
- **Marine Institute (MI)** – led by Glen Blackwood, MI is the largest marine research institute in Canada and works closely with industry to answer research questions of importance to the economic development of NL, in the areas of fisheries, maritime operations, ocean safety and ocean technology.

  Facilities include the Centre for Marine Simulation, Offshore Safety and Survival Centre and the Centre for Applied Ocean technology. In the last 10 years, MI has received more than $10M from the oil and gas sector.

4.2.2 Dalhousie University

Dalhousie University is the largest in the region and one of the oldest in Canada, with over 20,000 students enrolled, 3,500 graduate students and 1,000 professors. Over $181M in research funding each year and 60 Canada Research Chairs and over 250 start-ups launched since 2005. Signature research clusters include:

- **Sustainable Ocean**
  - Changing climate effects on the ocean
  - Sustainable aquaculture and agro ecosystems
  - Sensors, analytics and autonomous vehicles
  - Ocean engineering, networks, communications, materials and tidal energy
  - Marine and environmental law, policy and governance
  - Cultural and social development of coastal landscapes and communities
  - Marine risk evaluation
- **Cleantech, Energy and the Environment**
  - Renewable energy generation, storage and fuels
  - Energy security
  - Clean water, clean soil, clean air
  - Clean and NextGen materials
  - Sensors, AI and data streams
  - Social and biophysical dimensions of resource and environmental sustainability

Some specific activities in these clusters include:

- **The Clean Technologies Research Institute** was established in 2017 to advance cleantech research at Dalhousie. It comprises 50 faculty members and many more graduate students and postdoctoral fellows from 6 faculties – Agriculture, Architecture & Planning, Engineering, Management, Science and Arts and Social Sciences. Some of the relevant focus areas include:
  - **Renewable Energy, Storage and Systems**
    - Dr. Jeff Dahn at the forefront of research and innovation in battery technology for 40 years. In 2016, Tesla signed a 5-year exclusive collaboration with the Dahn Lab (25 researchers), focused on increasing the lifetime, decreasing the cost and improving the energy density of lithium-ion batteries.
    - Dr. Mark Obrovac – NSERC/Novonix Industrial Research Chair in Advanced Battery Materials. Research lab focuses on the physics and chemistry of advanced Sodium-ion, Magnesium-ion and other Metal-ion batteries. Design, synthesize, characterize and test new materials for use in the next generation of practical battery technologies, specifically for use in electric vehicles.
    - The Renewable Energy Storage Lab led by Dr. Lukas Swan focuses on advanced energy storage solutions to allow for increase penetration of renewable electricity generators. Projects include repurposing EV batteries at a grid scale a mixed battery array, high voltage grid storage cell balancing and techno-economic modelling of energy storage systems.
    - Renewables – ongoing research in the areas of materials for photovoltaics, coupling light absorption to electrochemical reactions to produce hydrogen as well as tidal power.
  - **Clean Water, Clean Soil, Clean Air**
    - The Centre for Water Resource Studies led by Dr. Graham Gagnon is a team of 20 professors and researchers contributes to the development of:
      - Treatment technologies for contaminated aquatic environmental media;
      - Methods for the restoration of watershed interactions and hydrologic functioning of altered aquatic system; and
      - Assessment and monitoring tools for disturbed and restored aquatic systems.
    - The centre partners with a number of organizations, such as LuminUltra which specializes in the microbial testing of produced water.

4.2.3 University of New Brunswick (UNB)

The University of New Brunswick has an enrolment of 1,350 graduates and 7,300 undergraduate students with campuses in Fredericton and St. John's.

Approximately 75% of all research conducted in New Brunswick is conducted at UNB with an annual budget of around $50M, resulting in over 75 spin-off and start-up companies.

UNB offers over 75 undergraduate programs with a student to faculty ratio of 15:1 as well as 32 graduate programs.

Energy Research at UNB attracts average annual funding of $6.2M, involves 60 faculty across 14 departments and undertakes 65 projects per year. The team pursues discoveries and develops innovative technologies, with a focus on sustainability, across the full spectrum of energy transformation – generation, transmission and end use.

Relevant research institutes and groups within the university include:

- **The Emera & NB Power Research Centre** for Smart Grid Technologies is supported by an $11M+ investment for ongoing projects and led by the Emera Chair in Smart Grid Technologies. Current areas of focus are smart grid, integration of distributed energy resources (DER), energy storage technology and direct load control. UNB is a founding partner of the Smart Grid Innovation Network (SGIN) with NB Power and Siemens Canada to foster co-creation and testing of cutting-edge smart grid technology.
- **Centre for Nuclear Energy Research (CNER)** – specializes in water chemistry control and corrosion detection, monitoring and prevention including hydrogen effusion probes for monitoring feeder pipe corrosion. The centre also works with local technology companies Moltex and ARC, on Small Modular Reactor (SMR) technology.
- **Magnetic Resonance Imaging (MRI) Research Centre** – invented a family of new MRI methods permitting its application to a large range of materials. This work has resulted in the successful spin-off Green Imaging Technologies, specializing in drill core analysis for the petroleum sector.
- Led by Dr. Ali Ghorbani, the **Canadian Institute of Cyber Security (CIC)** conducts research into big security data analytics and visualization, risk management, intrusion detection and prevention, malware analysis, detection and mitigation. The CIC also supports the grid modernization work.
- **The Ocean Mapping Group** of the department of Geodesy & Geomatics Engineering is focused on the processing, visualization and interpretation of ocean mapping data with a specific focus on mapping the sea floor. The group is a leader in hardware and software for sonar scanning, achieving sub-6cm resolution in 3D mapping. The Fredericton based 3D Planeta has connections with this group and is supported by investments from the New Brunswick Innovation Fund and UNB directly through the Fraser Student Venture Fund. 3D Planeta uses its proprietary image fusion technology for 3D visualization of air, land and sea.

4.2.4 *The College of the North Atlantic (CNA)*

The College of the North Atlantic comprises 8,000 students per year and 700 faculty on 17 campuses throughout NL.

Ranked as the top college for applied research in Atlantic Canada and 16th overall in the country, CNA as a research budget of $3.8M in 2019/20 FY. 100% of the research at CNA is applied and, as no work is currently done directly with the offshore oil and gas industry, it represents an untapped resource for the industry.

CNA's capabilities lie in prototyping, process mapping and product and process enhancements. Facilities include a manufacturing technology centre for machining, welding, laser cutting, 3D scanning, etc. Project examples include:

- $500k, 2-year project with Rutter Inc. on their radar technology for identifying and characterizing oil spills. The project involved making the radar units smaller and increasing the power.
- $5.2M, multi-year project to develop mobile hyperspectral scanning to support the extractive resource industry in Atlantic Canada. The technology involves short wave and long wave infra red scanning of drill core to determine mineralogy. The technology has potential application to oil and gas exploration by determining oil content of drill cuttings and fingerprinting oil from offshore reservoirs. The project involves industry participation from Photon etc. (Montreal), The Iron Ore Company of Canada and Agnico Eagle.

4.2.5 *Ocean Frontier Institute (OFI)*

The OFI is a transnational hub for ocean research. Established as a partnership led by Dalhousie, MUN and UPEI, the institute connects government and researchers, focused on economic sustainability and economic benefit for the Blue Economy. The institute involves 200 investigators and 400 PhD students. O&G is not central to the mandate but central to the interest. Three primary types of activities:

- **SEED fund** – high risk, high reward projects at the high end of the innovation funnel. Researchers are provided a few thousand dollars to flesh out their idea.
- **Ocean Graduate Training** – provides two-way exchange of information with industry where the OFI informs industry on the cutting edge of technology and industry defines needs and supports graduate training.
- Larger projects are collaboratively funded with participation from industry, funding agencies like Mitacs, universities and OFI.

The institute has a budget of $220M over 7 years including $95M from the Canada First Research Excellence Fund (CFREF). Larger projects are collaboratively funded with participation from industry, funding agencies like Mitacs, universities and OFI. Relevant areas of research include:

- Monitoring of oil spills with genetic monitoring technology (with eDNA tech) as well as underwater ROV work to identify the 3D scale for the spills
- Miniaturization of nutrient flow sensors
- Underwater sound communication
- Data management and ocean observation
- Social license research investigating how industries gain social license to operate and how regulators respond to public opinion
- Note that all projects require involvement of indigenous communities

4.3 Incubators

Incubators serve as a critical support to entrepreneurs and early-stage companies, supporting them in the early months to years as technologies and business models are developed and commercialized. There are a few hundred incubators across Canada including a significant network in Atlantic Canada. Some are tied to Universities; some are supported by venture capital funds and others are sponsored by private industry. Services provided by incubators include:

1	Mentorship and support for entrepreneurs, from students to experienced professionals
2	Links to government grants and private capital
3	Facilities and shared services
4	Access to industry

4.3.1 Memorial Centre for Entrepreneurship (MCE)

The MCE focuses on supporting Memorial students. With annual budget of $500k, provided by provincial and federal agencies as well as donor companies, the MCE provides students with an opportunity to work on their ideas in an entrepreneurial work term. There is also an annual competition with a $25k award and direct exposure to VC funds and other accelerators. Some of the companies that have emerged from the program are:

- **Mysa** – developed a smart thermostat for electric baseboard heaters, an idea that resulted from energy audits on houses as part of a course. Also involved with Genesis, the company raised $9M in private investors including Pelorus VC.
- **CoLab** – following a placement at Tesla, the founders identified an opportunity to improve the sharing of 3D models resulting in a software suite to facilitate real time design reviews. They have since received funding from the Y-Combinator (accelerator) and several VC funds.
- **Breathe Suite, InspectAR and Matrix Flow.**

Photo Credit: MCE received GlobalNL's inaugural Community Impact Award - ttps://www.mun.ca/engineering/news.php?id=13922&type=news

4.3.2 Genesis Centre

The Genesis Centre is wholly owned by MUN and has been in operation for 23 years. Starting with an 8 week period to mold ideas, the Centre provides a 3 year program which includes a full suite of services from physical space, access to funding to shared services (HR, marketing, finance, management consulting). A typical entrepreneur has 10+ years of experience in industry and has a identified a solution to a problem they have encountered in their careers. One of the Genesis Centre's cleantech focused initiatives is a collaboration with SDTC, in which it brings forward two companies every two months as suggestions for SDTC's Seed Fund, providing $50k to $150k grants. The Genesis Centre is funded from a range of sources, including revenue from its graduate companies – once a company achieves $1M in revenue, they return 2% of gross sales for 5 years. Some of its success stories are:

Virtual Marine	Simulation services for offshore workers
MYSA	Smart thermostats for residential electric baseboard heaters and air conditioners
Seaformatics	Wind and water turbine for rechargeable portable electronics
Rutter	Developed "black box" for ships, now focused on radar based oil spill and iceberg detection
SkyHawk Telematics	Tracking systems for municipal vehicle fleets
Solace Power	Wireless power technology for automotive applications

4.3.3 Ocean Startup Project

An initiative funded by the Ocean Supercluster, the Ocean Startup Project aims to start, grow and foster blue tech companies. It is a Pan Atlantic collaboration between 6 organizations: Genesis, Innovacorp, New Brunswick Innovation Foundation, Creative Destruction Lab, PEI BioAlliance and Springboard Atlantic. The group started by surveying industry – 50 organizations across Canada, including Chevron, Clearwater and Emera – to frame challenges. A call for solutions was issued in 2020 with 14 companies selected from 158 applicants to receive the $25k award. A total of $1.4M will be available for next year, $100k for each award, with a call scheduled for mid-2021.

4.3.4 Centre for Ocean Ventures & Entrepreneurship (COVE)

COVE is anu industrial growth hub focused on the ocean economy, specifically offshore energy (renewables and oil and gas), marine tourism, transportation, defense, fisheries and aquaculture. The centre hosts 70 organizations at its physical location in Dartmouth, NS, ranging from start-ups to satellite offices of multi-national corporations looking to gain insight into developing, disruptive technologies or to showcase their own developments. Facilities include office space, manufacturing facilities, waterfront laydown area and wharfage, 4 berths to dock larger ships and floating docks to support development activities. COVE is a not for profit with industry funding provided by Irving Shipbuilding. The property and facilities are owned and managed by Develop Nova Scotia.

A workforce initiative fosters the next generation of talent through development of educational materials and targeted intern programs to bring students to the workforce. A technical program develops offshore and on shore shared infrastructure, such as a buoy system and subsea cable array, which support development of data collection technologies.

Key areas of activities include autonomous vehicles and sensors. Kraken (subsea robotics) conducts testing at COVE and has worked with Emera. X-Ocean develops surface drones and Spiri Robotics is developing air drones for data collection and operate as autonomous fleets. A number of companies are working in the sensor space including:

RBR	Oceanographic sensors such as water salinity, temperature
Dartmouth Ocean Technology (DOT)	Phosphate sensors and environmental DNA sampling
Xeos	Environmental sensing
ProOeanus	Dissolved gas sensing (i.e., CO_2)
Sensortech	High frequency hydrophones
PanGeo Subsea	Multi-beam sonar for seafloor imaging
Rimot	Sensors for the autonomous operation of sea vessels and data analytics

4.4 R&D Facilitators

There is a legislative requirement for operators to spend a portion of revenues on research, development, education and training (R&D/E&T). In NL, from 2004 to 2016, this amounted to $500M and since 2017, this amount has been capped at 0.5% of revenues. PRNL manages a portion of this expenditure on behalf of the Operators. In Nova Scotia, OERA serves a similar role, however, with the shutdown of Sable and Deep Panuke in 2018, OERA is expanding its focus to include the broader energy system. Both organizations support ongoing Research and Development and represent an important resource for developers of new, relevant technologies in the cleantech space.

4.4.1 Petroleum Research Newfoundland & Labrador (PRNL)

PRNL represents the collective R&D efforts of its members, Chevron, ExxonMobil, Husky Energy, Equinor and Suncor Energy. PRNL manages about 10% of the operators R&D/E&T commitments and have managed over $60M since 2012. Research focus areas are Health & Safety, Environment, Maximizing Economic Recovery of Resources and Integrated Operations. Funding mechanisms include Expression of Interest, Calls for Proposals, Academic Research Funding and Unsolicited Proposals.

Reducing emissions and carbon intensity of new and existing operations is an emerging area of focus for PRNL. Of NRCan's recently announced $750M Emissions Reduction Fund, $75M will be dedicated to the offshore industry and, of that, $33M will support research, development and demonstration projects that advance solutions to decarbonize NL's offshore industry. This portion will be managed by PRNL. A call for proposals was issued in December 2020 and as of February 2021, proposals are being assessed with awards planned for March.

Operational efficiency is a key focus area for reducing emissions. To this end, PRNL has led the development of the Digital Offshore Canada project, funded by the Ocean Supercluster, the Operators and partners Virtual Marine, GRi Simulation, Hatch and MUN.

4.4.2 Offshore Energy Research Association (OERA)

OERA is an independent non-profit organization that enables expert energy research carried out by collaborative, made-to-order teams. The organization works with consortia of academic, government and industry partners to build and share intellectual property.

Since its inception in 2006, OERA has directed more than $40M of public and private sector research investment across 200 projects. OERA's work helps solve challenging problems, answer key questions and make technical advances, supporting economic growth and sustainable energy development in Nova Scotia.

With respect to cleantech, OERA has undertaken a number of recent initiatives. The organization is leading research related to both, on and offshore renewables, including offshore wind and tidal energy, with areas of exploration including policy and regulatory best practices, resource characterization and infrastructure considerations. Another recent study examined the potential for regional involvement in the hydrogen economy, looking at production, storage, import, use and its potential role in the energy transition. Other current topics include geothermal energy, battery storage, carbon capture and sequestration and regional energy system modelling.

4.5 Funding Agencies

The cleantech innovation ecosystem in Atlantic Canada is supported by $100's of millions in government funding spanning all stages of development and commercial application from early-stage research at universities and colleges through to capital improvement projects at large operators. Funding ranges from grants to repayable loans and equity investments. Outside of funding to post secondary institutions (but not exclusively) funding typically requires participation of industrial partners and a clear path to commercialization. All funding organizations include in their focus areas a goal to reduce GHG's, aligned with Canada's commitment to achieve net zero by 2050.

4.5.1 Natural Science and Engineering Research Council of Canada (NSERC)

NSERC provides $1.3B/yr. to universities and colleges and supports research of about 12,000 professors and 30,000 students, most at the masters and PhD level. All awards are made based on merit and fall into one of three pillars:

- **Curiosity Driven Research** (about 50% of all funds)
- **Scholarships** – money provided direct to students
- **Alliance Grant** – a partnership fund of $350M/year, requiring a partnership with public, private sector or not for profit organizations. The funds are provided directly to the Universities and NSERC will match 1:1 contributions from larger organizations and 2:1 for smaller organizations.

4.5.2 National Research Council – Industrial Research Assistance Program (NRC-IRAP)

IRAP provides SME's (500 employees or less) with funding and networking support for projects to develop disruptive technologies typically TRL 4-6. One of the key requirements for funding is a clear commercialization plan. The fund covers salaries and contracts.

Projects are funded at levels from below $50k to greater than $1M, with increasing levels of rigor in approvals depending on the amount. IRAP will cover to a maximum of 50% of the project costs and the company must provide at least 25%. Projects will typically follow a multi-year plan and IRAP will support through to proof of concept. After one year, other government and industry support will be required.

4.5.3 *Government of Newfoundland and Labrador*

The Ministry of Industry, Energy & Technology seeks opportunities to help companies to innovate, enhance competitiveness, develop new products and develop export markets. This fiscal year, $13M worth of projects are approved or in process, supporting commercial R&D. Each leverage one or two industry participants, typically an SME working with a larger company (e.g. Tier-1 or Operator). Funds may be provided to commercial and non-commercial projects, typically 50% but up to 75% of project salaries and expenses.

Annual spending, specifically on Energy related projects, over the past 10 years, range from $500k to $13.5M, for a total of $43.2M. About 70% of that was for non-commercial projects with the majority of those led by MUN.

4.5.4 *Business Development Bank of Canada (BDC)*

BDC is the financial institution devoted to Canadian entrepreneurs providing financing, advisory services and capital investment. It is a financially sustainable Crown Corporation operating at arm's length from its sole shareholder, the Government of Canada, with $36.5B committed to small and medium-sized businesses. Last year, extra financing was budgeted for companies servicing the oil and gas sector and in 2018, a $600M cleantech investment fund was launched.

4.5.5 *Export Development Corporation (EDC)*

EDC is a Crown corporation dedicated to helping Canadian companies of all sizes succeed on the world stage, providing trade knowledge, financial solutions, equity, insurance and connections. EDC provides:

1	Credit Insurance
2	Financing
3	Access to working capital, in partnership with banks, by providing guarantees
4	Direct lending, participating in syndicate deals as gap filler
5	Bid, performance bond guarantees
6	Connections – act as match maker between Canadian companies and international client.

In the past few years, EDC has affirmed commitments to carefully monitor and reduce lending in carbon intensive sectors and focus energy on introducing Canadian cleantech companies to international clients, providing solutions that reduce emissions, reduce impact on environment, reduce spills and improve energy efficiency.

4.5.6 Sustainable Development Technology Corporation

SDTC is funded by the Canadian government with a mandate to invest in pre-commercial technologies with a positive impact on Climate Change, Air, Water and Soil. It has invested 1.1Billion over 20 years with a faster rate of investment ($100-150M/yr) over the last 3 years with greater volumes of deal flow.

With respect to oil and gas sector, it has worked extensively in Western Canada with a goal to expand its involvement on the East Coast over the last few years. SDTC relies on the local innovation ecosystems to feed new projects.

A new initiative, the Seed Fund, provides grants of $50 to 150k with a short application process. This is in contrast to conventional grants of $1 to 5M which it concluded were less accessible to smaller, earlier stage companies. SDTC works with local incubators and accelerators such as Genesis, Energia Ventures, Votal, Innovacorp, Verschuren Centre, and the Ocean Startup Project.

4.5.7 Atlantic Canada Opportunities Agency (ACOA)

ACOA is an agency of the Government of Canada, with a mandate of economic development for Atlantic Canada. It helps startups, new businesses and existing business to expand (vertically, geographically, etc.) and innovation is a high priority.

ACOA supports the development of the oil and gas industry, working with NRCan, CAPP, C-NLOPB and the Provincial Government and will advocate on policies, rules and regulations federally that may unfairly impact the offshore industry.

ACOA will provide interest free, unsecured, 100% repayable financing to SME’s in the region. Innovation projects and projects for export markets are conditionally repayable. On capital projects, ACOA may provide up to 50% of the cost, with typical limits of $500k but this can be exceeded where there is merit.

4.5.8 *Ocean Supercluster (OSC)*

The OSC is an industry led organization with around 350 members, 65% of those are from the private sector. With an original allocation of $153M over 5 years (starting in 2018) provided by Innovation, Science and Economic Development Canada (ISED), the OSC will support a portfolio of collaborative development projects with a total investment of $400-500M, including contributions from the collaborating companies. The program is roughly half committed with over $200M in total project value announced or approved. While the future of the OSC beyond its original mandate remains an open question, it is most likely that the focus on sustainability and environmental impacts of the projects will increase.

Projects are focused on three core areas – environment, data and visualization and operational improvement. Membership represents all ocean related sectors including energy, shipping, biotech, transportation, fisheries and aquaculture and while the center of gravity lies in Atlantic Canada (90% of the projects have at least one AC participant), there is no geographic mandate and cross country collaboration is a key aspect of many projects.

Some of the key themes drawn from current projects include:

- Hybridization of propulsion systems;
- Fuels for marine applications resulting in reduced emissions;
- Biotechnology;
- Digitalization – Remote monitoring, digital twin, simulation, data analytics;
- Autonomous robotic vehicles and sensor technology;
- Advanced coatings for vessel fuel efficiency; and
- Smart grid.

4.5.9 *Natural Resources Canada (NRCan)*

The Government of Canada provides substantial funds to support research, development and demonstration of cleantech projects and these can be accessed through The Clean Growth Hub. NRCan provides a large portion of this funding through open calls for proposals around specific themes and is currently supporting cleantech projects in Atlantic Canada totaling $100M, for a total projects budget of $300M. Project topics are tidal and renewable power, carbon sequestration, smart grid and EV charging, and oil spill response.

The $750M Emissions Reduction Fund was launched October 29, 2020 to help oil and gas companies reduce methane emissions, aligned with Canada's commitment to achieve net zero by 2050 and exceeding Paris Agreement targets by 2030. Within this fund, $75M will be invested in the offshore oil and gas industry:

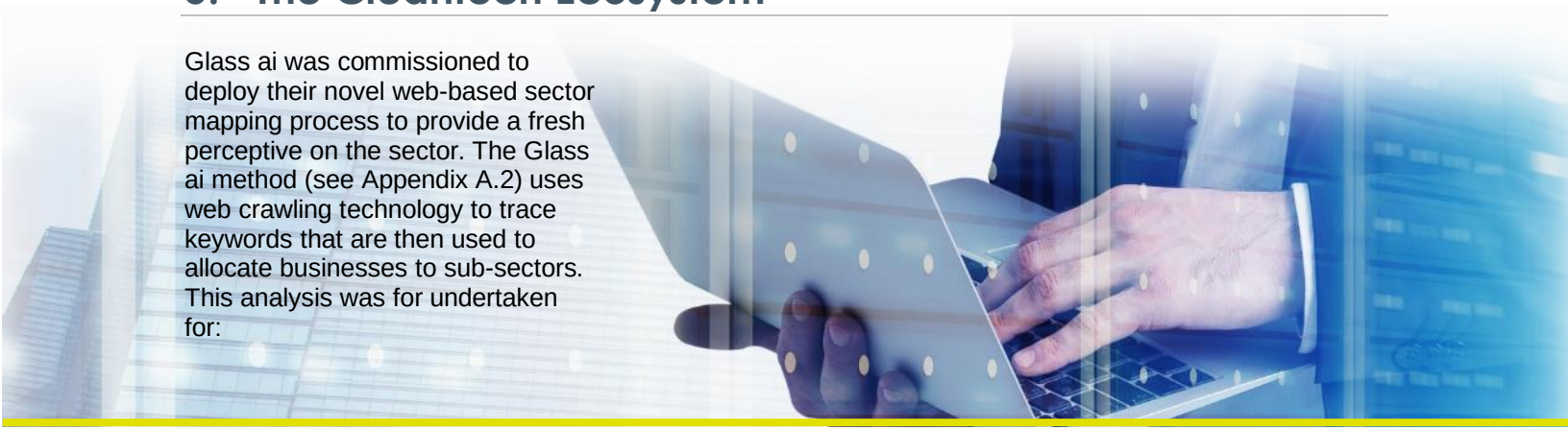
- The Offshore Deployment Program, $42M, will support capital projects which reduce GHG's or improve performance of offshore oil spill monitoring, detection and response.
- The Offshore RD&D Program, $33M, will advance solutions to decarbonize, NL's offshore industry. PRNL will administer this fund.

05
The Cleantech Ecosystem

NEIA / Noia Clean Technology Landscape

HATCH

5. The Cleantech Ecosystem



Glass ai was commissioned to deploy their novel web-based sector mapping process to provide a fresh perceptive on the sector. The Glass ai method (see Appendix A.2) uses web crawling technology to trace keywords that are then used to allocate businesses to sub-sectors. This analysis was for undertaken for:

- Stakeholder institutions that support the sector, made up of oil and gas operators and Tier-1 companies as well as universities and sector representative bodies/associations; and
- The wider base of private business supplying and developing cleantech solutions from a base in Atlantic Canada.

The output from Glass ai was used to

- Provide a landscape overview of both the stakeholder institutions and private businesses in the four broad areas of cleantech as described in Section 2. The output of the overview can be found in Appendix A.3
- Provide a shortlist of relevant private business outside of the stakeholder institutions for targeted survey.

The shortlist of private businesses outside of the stakeholder institutions was then filtered manually to pick the most relevant companies in the cleantech space in order to eliminate any false results from Glass ai output. These private businesses are those which are not categorized above as oil and gas companies/operators, Tier-1 contractors, post-secondary institutions, funding agencies, R&D brokers and utility companies.

The filtered shortlist was supplemented with selected members from the association list missing from the Glass ai output. In total, the number of businesses filtered and shortlisted for survey was 279. However, the survey was sent out to only about 176 companies as the contact information of the remaining companies was missing and could not be sourced within the time this study was allocated.

5.1 Business Survey

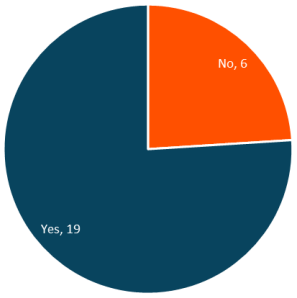
5.1.1 Summary of Reponses Rate

We undertook a short web survey of the offshore oil and gas sector private business base across Atlantic Canada. Invitations were issued to 176 companies known to operate in and around the cleantech agenda to understand their engagement in innovations and the barriers/drivers shaping their approach. A copy of the survey is included in Appendix A.4

The survey ran from the 13th of November to the 11th of December had only a limited success, securing only 25 responses. Nevertheless, we believe there are some helpful insights in the responses which could be used to help partners better understand how to encourage more businesses to engage in cleantech innovation and how to encourage a further involvement among those businesses that have already entered the arena.

Table 5-1: Is your Company currently Supplying Cleantech Products and Services Relevant to the Offshore Oil and Gas market?

Is your company currently supplying cleantech products and services relevant to the offshore oil and gas market?	
No	6
Yes	19
Grand Total	**25**



Although caution should be applied to the results, nearly three-quarters of the respondents were already delivering cleantech services relevant to the offshore oil and gas market. We are not able to divulge details of the innovations that companies are engaged in; however, a sample of the sort of keywords used when respondents described their activities and drivers include:

- GHG inventories
- International Maritime Organization 2020 sulphur cap
- LPG/LNG vessels
- Mud Slops Disposal
- Washing Treatments
- Oil Spill Detection
- Software to support HSE, asset management and emergency response.
- Digital sensor and Predictive Analytics for efficient and cleaner operations
- Valve monitoring / diagnostics
- Battery energy storage
- Asset management
- Green hydrogen production
- Substation EPC
- Environmental genomics for biodiversity monitoring and detection of rare, endangered or invasive species
- Waste management solutions
- Hydraulic oil filtration
- Environmental quality monitoring
- High-fidelity simulation and visualization of oil spills
- Underwater noise modeling, measurement,
- CO_2 capture and removal of NOx, SOx

5.1.2 Non-Adopters

We asked the six businesses that had not engaged in cleantech to identify the barriers that they believed stood in the way of their business getting involved in cleantech.

We have not entered the market because	No. of Responses
We cannot see a gap in the market	3
It is too costly to explore	2
We believe the end market is too small relative to the cost and complexity of developing solutions	2
We have too little technical knowledge	1
The prospects are too risky	1

Clearly the low response rate makes it hard to draw any conclusions, however if this spread of reasons were replicated on larger sample, it would indicate that the reasons for businesses not adopting cleantech solutions are reasonably broadly cast, but the highest rated factor is identifying a gap in the market that their company could exploit. We further asked the non-adopters what might stimulate their interested in cleantech solutions.

We would be interested in developing new cleantech solutions if…	No. of Responses
We had help to understand how best to progress	6
Had access to more suitable investment funds	4

All of them said they would be more likely to respond if they had help to better understand how to progress towards solutions and two-thirds suggested that better access to suitable investment funds would help.

We also asked what they felt the driver might be that actually got hem to get involved in cleantech. We provided a series of prompts and asked respondents to state how important they might be.

If your company were to invest in clean teach, what would be the drivers for your company?						
	Customer demand	**Access to technology locally**	**Access to provincial/ federal funding**	**Long term strategic commitment to continuous innovation**	**Sole initiative of an individual or individuals within the company**	**Regulatory driver**
VERY IMPORTANT *(Critical to the decision)*	5	2	1	1	1	0
IMPORTANT *(But not enough on its own)*	1	1	3	2	1	3
SOMEWHAT IMPORTANT *(But not a major factor)*	0	1	2	3	4	2
NOT RELEVANT	0	1	0	0	0	1

It is clear that customer demand will be vital in encouraging non-adopters to get engaged in cleantech innovation. Thereafter, access to technology and funding will play a role, while developing a long-term commitment to continuous innovation and/or having an individual with the drive to implement innovation could also play an important supporting role to get more businesses engaged in cleantech innovation.

Caution should be applied in interpreting these results but if replicated on a larger sample, they would suggest that regulatory drivers have a lower order role to play. This may however reflect business' expectations about future new regulations rather than the substantive role regulation has to play in general.

5.1.3 Cleantech Innovation Adopters

A slightly different set of questions were asked of the larger group of businesses that had already adopted cleantech innovation solutions. Firstly, we asked them a general question to describe how their innovation was progressing. Respondents were allowed to select more than one option.

Which of these best describes your company's views on the market for clean teach solutions that you are currently operating in...	No. of Responses
Going well and we expect to achieve our objectives	10
Going well and we are planning to scale-up our investment	8
Proving risky and complex	5
Proving very costly	4

Just over half (10) signaled their views on the market for clean teach solutions were going well and that they expect to achieve their objectives. A slightly smaller number (8) were planning to scale-up their investment. The number encountering a more adverse situation were in the minority – just a quarter were finding it risky and complex and/or costly. This however is not surprising and should be considered a reasonable low figure given the costs and complexity involved in diversification in the oil and gas sector. This low figure may in part be explained by a degree of self selection in the survey responses i.e., those businesses doing better are more likely to participate in a survey on cleantech innovation.

Busineses were asked to give a sense of the scale of their company's investment in cleantech innovation and an indication of how much of it was taking place in Atlantic Canada.

Four of the respondents have invested over 20% of their company revenues in cleantech over the last 3 years, while at the other end of the spectrum seven had invested less than one percent. The larger investors do however appear to concentrate more of their investment in Atlantic Canada – indeed on closer investigation it may be the case that these businesses are solely focused on cleantech and operate entirely in Atlantic Canada. On the other hand, most of the businesses that invest less than one percent of their revenues in cleantech, also do very little of it in Atlantic Canada.

If your company were to invest in clean teach, what would be the drivers for your company?	How Much is Taking Place in Atlantic Canada					
	None	<10%	50-75%	75-99%	100%	Total
<1%	4	1			2	7
1-3%		2				2
3-5%	1			1		2
5-10%	1				1	2
10-20%			1	1		2
20%+			1	2	1	4
Grand Total	6	3	2	4	4	19

The survey asked respondents to indicate which drivers had been most important in their company's decision to get involved in cleantech. The responses reveal that a long-term commitment to long-term strategic commitment to continuous innovation and customer demand are the two top rated factors. Access to provincial/federal funding, regulatory drivers and individual's initiative were middling factors and access to technology locally was the lowest rated factor.

What were the drivers behind your company's decision to be involved in cleantech?						
	Long term strategic commitment to continuous innovation	Customer demand	Access to provincial/ federal funding	Regulatory driver	Sole initiative of an individual or individuals within the company	Access to technology locally
VERY IMPORTANT *(Critical to the decision)*	15	15	7	6	4	2
IMPORTANT *(But not enough on its own)*	4	3	6	8	5	6
SOMEWHAT IMPORTANT *(But not a major factor)*	0	1	1	4	5	7
NOT RELEVANT	0	0	5	1	5	4

Although we should be cautious when interpreting the survey results, if the same response were generated in a larger sample, it would not be unreasonable to conclude that Atlantic Canada could:

- Encourage more businesses to engage in cleantech opportunities by helping non-adopters to better understand
  - the scale and nature of current and future customer demand
  - and the pathways to implementing innovation in their businesses

This could be achieved by working with Tier-1 companies and operators to better articulate the evolving nature of industry requirements and developing a support programme to help innovation-curious businesses to support employees and directors to help establish a strong innovation culture in their business and to drive forward new product and processes.

- Explore increasing the commitment of companies already engaged in cleantech through targeted effort focused on businesses already doing some innovation locally and supporting their intensification efforts by
  - helping them further develop an innovation culture in their company for the long term
  - and (as with non-adopters) better articulating of the demands of clients in the oil and gas marketplace
  - Given the small sample size, these tentative findings should be further tested with a wider set of businesses before any new support provision is developed or put in place

5.2 Private Businesses Mapping to Sector Challenges

The intent of the survey carried out was to collect responses and categorize capabilities of each private business to challenges faced by offshore oil and gas industries in Section 3.2.

Due to the lack of timely responses, semi-automatic identification and manual verification of the relevant private businesses in each challenge category were performed with the help from Glass ai's original output. Each challenge was assigned a set of keywords relevant to the challenge as detailed in Appendix A.2. For each sector challenge, the private business from Glass ai was once again filtered and ranked based on the number of keywords mentioned relevant to each challenge in the evidence gathered by Glass ai.

Table 5-2 shows the summary of private businesses with capabilities relevant to each sector challenge.

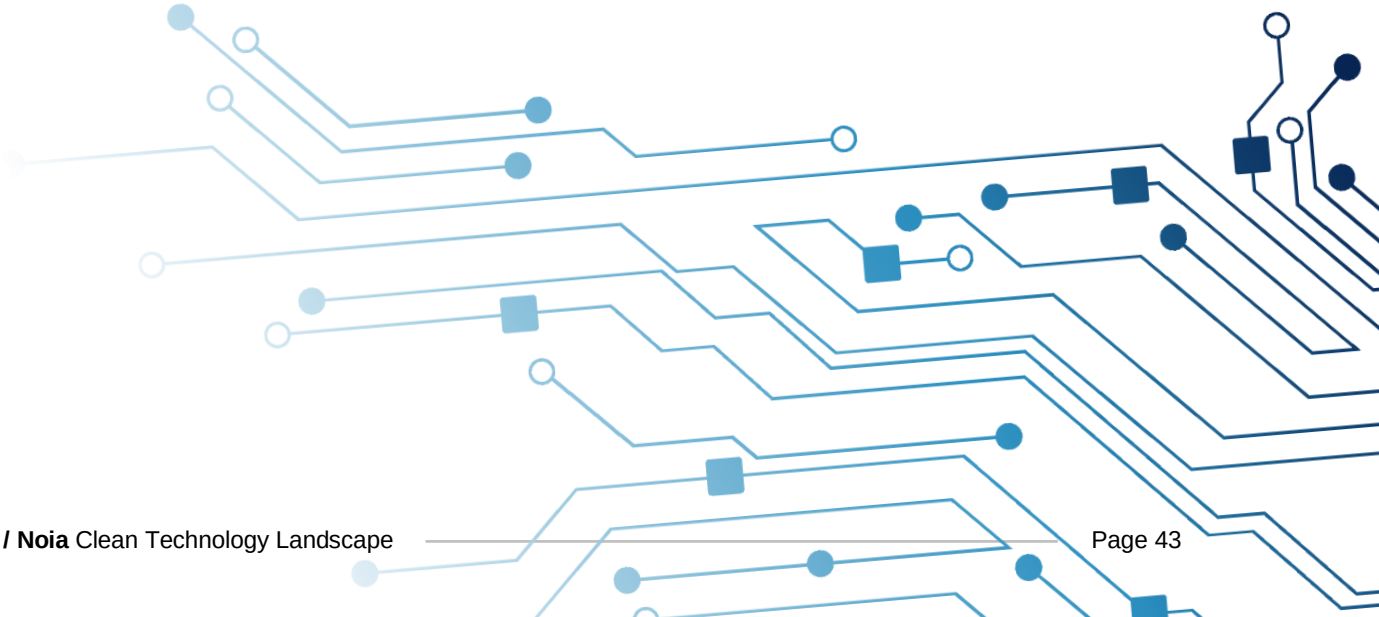


Table 5-2: Private Businesses Capabilities Mapping to Sector Challenge

No.	Sector Challenges	Private Businesses	Summary of Capabilities
1	**Environmental Sensing, Monitoring and Characterization** *(Continued on following page)*	• C-Core	Remote Sensing, oil spill response technology, Ice Engineering (detection, digital classifier, satellite tracking), 3D simulation of Iceberg Towing Operations, Pipeline Ice Risk Assessment and Mitigation (PIRAM)
		• eDNAtec	Environmental genomics (DNA-based) technologies such as DNA characterization of hydrocarbons.
		• GRi Simulations	World leader in software development and integration of computer modeling and simulation applications in underwater Remotely Operated Vehicle (ROV) system operations and design. Virtual ROV (VROV) line, are directed towards support of ROV pilot training, and mission planning and rehearsal for subsea oil field construction and production support activities.
		• Rutter	Leading edge of radar high-definition image processing technology for the global marine sector. 20 years experience in navigate safely through ice-hazards; detect and respond to oil spills; protect people, assets and coastlines, and conduct ocean-related research. Application in Iceberg/Sea Ice Detection and Analysis • Surveillance | Search & Rescue • Port and Harbour Security | Antipiracy • Oil Spill Detection and Management • Wave/Current Monitoring and Analysis
		• Kraken Robotics	Marine technology company engaged in the design, development and marketing of advanced sensors for Unmanned Underwater Vehicles used in military and commercial applications. World leading innovators of Synthetic Aperture Sonar (SAS), a revolutionary underwater imaging technology that improves seabed surveys with ultra-high-resolution imagery.
		• Edgewise	Marine mammal/Seabird observation and Acoustic monitoring
		• Pangeo	Geophysical/geotechnical service and survey. Specializing in 3D and 4D acoustic imaging solutions that mitigate risk and create value for oil and gas and other energy industries
		• SubC Imaging	Imaging equipment in remote harsh environments Application in remote vehicle operations including deep sea mining, marine research, archaeology, and in offshore oil and gas service work.
		• 3D Planeta	3D image fusion and visualization platform, Navec™, provides unprecedented awareness of terrain, structures and objects of interest in 3D aerial images and giving operators and analysts the ability to assess the terrain in true 3D. It helps quickly assess immediate critical needs, such as emergencies or natural disasters.
		• RPM Aerial Services	Unmanned Aerial technology (RPAS) and internally developed attachment systems to quickly, efficiently and effectively attach GPS tracking technology to icebergs for risk mitigation. Potential RPAS application (under development) to monitor emissions/conditions in an offshore environment and reduce oil spill response times significantly.
		• Ocean Sonics	Seismic Surveys, pipeline leak detection and underwater acoustic-based monitoring. Digital hydrophones for gathering underwater sounds. The icListen Smart hydrophone is used by researchers, scientists, and offshore operators.

No.	Sector Challenges	Private Businesses	Summary of Capabilities
		• Altomaxx	UAV/RPAS/Drone training and service company in the Offshore Oil & Gas, Mining, Emergency Services and private sector.
		• Compusult	Global leader in geospatial Interoperability. Environmental data acquisition and management. Provide solutions for geospatial data discovery, access and delivery
		• Green Imaging Technologies	Nuclear Magnetic Resonance (MNR) based well log calibration and analysis. 3D imaging of rock cores using NMR and MRI instruments
		• Spiri Robotics	Autonomous robotic inspection and data collection, combined with data analytics. Currently developing Pleiades Robotics to prepare Spiri drones for ocean-based science, security, commerce and stewardship.
		• Pro-Oceanus	Dissolved CO_2, CH_4 and Total Dissolved Gas Pressure (TDGP) sensors in ocean, wastewater and industrial processes. Largest range of submersible dissolved CO_2 sensors in market.
		• Dartmouth Ocean Technologies	V-Wing, Portable Underwater Mapping, Research, and Reconnaissance. Phospate Sensor: In-situ Nutrient Detection.
		• Xeos	Ocean Surface and sub-surface Telemetry Tracking Equipment and Solutions.
		• JASCO applied sciences	Specialized underwear acoustic monitoring, Noise Impact assessment & Mitigation & Data analytics
2	**Production Efficiency Optimization**	• Virtual Marine (simulation) • GRi Simulation • MNP	Virtual Marine develops customized virtual reality simulators using vessel-specific equipment for Lifeboats and Fast Rescue Boats (FRB). . VMT's simulators combine high fidelity sensory cues with tailored curriculum to enhance small craft training programs.
3	**Gas Turbine Emissions Reduction & Electrification** *(Continued on following page)*	• C-Core	Iceberg risk management on renewable infrastructure
		• Green Power Labs	SMART Grid solution
		• Fundy Ocean Research Centre for Energy (FORCE) – Tidal	Canada's leading test center for in-stream tidal energy technology. Working with developers, regulators, and researchers to study the potential for tidal turbines to operate within the Bay of Fundy environment.
		• DP Energy – Tidal & wave	Assess resource and develop both tidal and wave energy site worldwide.
		• RtTech	RtDUET : a real-time software solution designed to increase productivity through Asset Management, Asset Health Monitoring, and Downtime Tracking. RtEMIS : an Energy Management Information System, designed to help industrial facilities reduce energy consumption and increase energy efficiency.
		• Atlantic Combustion Technologies	Biomass to Energy
		• Aspin Kemp Associates	Marine Vessel Hybridization. Hybrid Drill Floor. Partnership with MAN energy solution. Systems integrator and engineering company delivering innovative solutions to island and microgrid power system.
		• Solace	Providing turnkey solutions for applying technologies to switch from pneumatic devices to electrification

No.	Sector Challenges	Private Businesses	Summary of Capabilities
		• Carbon Cure	Removal of CO_2 (sourced from industrial emitters) by injecting into concrete to form nano-size mineral, making stronger concrete.
		• Brezo Energy	Sea-Breeze Tech – Pioneering New Floating Wind Power design for offshore wind farms
		• Moltec	Small modular Nuclear Reactor
		• ARK	Small modular Nuclear Reactor
4	**Flaring Reduction and Recovery**	• VELAN Valve	Improve valve control to reduce emissions (not AC)
		• Axess Baffin	ALPA double retention winching system, inherently safe design to increase uptime and reduce flaring during lifting over wellhead.
		• Score (Canada)	Intelligent valve management ™ to detect valve leakage and lower emission such as flaring
		• Aspin Kemp Associates	Improved systems fault detection and increase availability
5	**Hazardous Offshore Discharges and Disposal**	• LuminUltra	Microbial testing of Produced Water
		• Evoqua	Water Technologies for oil removal, wastewater treatment, marine growth prevention, saltwater disposal well (SWD) well filtration solutions.
		• Oil Filtration Solutions (OFS)	Filter system highly efficient in the removal of ultra-fine contamination and water normally missed by the main filters. By filtering oil down to 1 micron, with the added ability of removing water at 99.97% from oil
		• Terrapure Environmental	Battery and Oil recycling solutions
		• Sustane	Transforming municipal solid waste back into raw materials (e.g. biomass pellets, synthetic diesel)
6	**Oil Spill Emergency Response** *(Continued on following page)*	• ECRC	Administers Offshore oil spill preparedness program on behalf of operators
		Detection and Mitigation	
		• eDNAtec, Rutter	See above

No.	Sector Challenges	Private Businesses	Summary of Capabilities
		• C-Core	Mechanical recovery and oil spill response
		• Hi-Point Industries	Producing environmentally safe, all-natural oil absorbents for the containment of hydrocarbon spills. Manufacturer of Oclansorb®, Sorb-Sox®, Horticultural Peat Moss, Floating Oil Containment Boom, Flexible Containment Berms, Spill Kits, and other custom products.
		• Provincial Aerospace	Global Leaders in Airborne Maritime Surveillance, intelligence, surveillance, reconnaissance (ISR) and maritime patrol aircraft (MPA) operations and systems. The Environmental Services Division of Provincial Aerospace Ltd. provides ice management service primarily to the Grand banks and Arctic oil and gas industries. (inc. weather and ice observation and serial reconnaissance)
		• Nord Marine	Safety evacuation equipment (boats, life jackets, etc.) for offshore oil and gas industries and oil spill response products (Oil Spill Containment, socks, booms, pillows, sorbent pads, spill kits.
		• Pro-Oceanus	Sensors to measure CH4 dissolved in water for well blow-out spills
		• Xeos	Oil spill surface tracker (OSKER, ROBY) : 2-way communications coverage oil spill and ocean current tracking via the Iridium satellite system with on-board programming.
		Training	
		• Virtual Marine, GRi Simulation, Nord Marine	See above
7	**Logistics Transportation Optimization** *(Continued on following page)*	• AxessBaffin:	Mechanical flare tip replacement solutions (vs. helicopter)
		• Genoa Design	3D modeling to shipbuilding from concept to decommissioning
		• Cougar Helicopters	Helicopter Transport
		• Altera Infrastructure	E-shuttles – Crude oil tanker with battery-powered, LNG as fuel, Fuel optimized design, onboard VOC
		• ASCO Canada	Digital twin of offshore supply base to increase efficiency (reduce waiting time on trucks and vessels)
		• Focus FS	Software for safer, efficient worksites, streamlining equipment management

No.	Sector Challenges	Private Businesses	Summary of Capabilities
		• Blue Water Group	Supply Chain Logistics
		• Atlantic Towing	Hybrid battery-diesel-electric propulsion Platform Supply Vessel
		• SkyHawk Telematics	Advanced fleet telematics solutions for governments, public works, winter operations and power utility sectors within North America. The SkyHawk – ConnectAnywhere™ cloud-based monitoring service provides fleet connectivity and operational intelligence by utilizing the cellular, satellite, and sensor networks available.
		• Mara Renewables	Algae-based biofuel
		• BRezo Energy	Ship Design
		• Dominion Diving	Customised integrated service for marine based operations for transporting of equipment and specialized personnel.
		• McKeil Marine	Comprehensive Marine service offerings (Transportation, Towing, equipment rental and Logistics Studies) to maximize efficiency, reducing costs and environmental impact
		• Duxion Motors	Advanced Hybrid Marine Propulsion System. Technology allows for the hybridization of in-service ships to be retrofitted with hybrid-electric propulsion systems that integrate directly with existing hardware.
		• Redrock Power Systems	Hydrogen Fuel Cell/Battery System for Marine. Zero-emissions hydrogen fuel cell technology for shipboard power generation and propulsion. European partners in the areas of advanced marine propulsion batteries and Air Supported Vessel technology (ASV).
8	**Remote and Integrated Operations**	• C-Core, GRi Simulations, Kraken Robotics, Edgewise, Pangeo, SubC Imaging, 3D Planeta, RPM Aerial Services, Ocean Sonics, Virtual Marine, Altomaxx, Focus FS	See above
		• SmartICE	Technological innovation, world's first climate change adaptation tool to integrate traditional knowledge of sea ice with advanced data acquisition and remote monitoring technology.
		• Oceaneering	A subsea connection and survey specialist. The world's largest ROV operator and the leading ROV provider to the oil & gas industry with over 300 systems operating worldwide. Pushing the limits of ROV intervention and meet new, demanding tooling intervention.

No.	Sector Challenges	Private Businesses	Summary of Capabilities
		• Solace	Equus™: Modular Wireless Power Platform, delivering wireless power at greater distances
		• Spiri Robotics	See above.
		• Rimot.io	Rimot monitors, controls and provides insights into remote critical infrastructure through the use of enabling technologies such as data analytics, security and advanced networking. Industrial Internet of Things ecosystems, IOT security.
		• Dominion Diving	Remotely operated underwater vehicle (ROUV) Service

5.3 Electric Utilities

As the providers of sustainable, reliable electrical energy, the regional utilities will play a significant role in the energy transition that will accelerate with the move away from carbon intensive activities. In the offshore context.

Overall, the Atlantic Canada region has a relatively low carbon supply of electrical energy, with 80% of all electrical energy generated in 2018 coming from renewable or nuclear sources. NL produces 2/3 of the energy for the region and 95% of that is hydroelectric with a portion of this sold to Quebec.

5.3.1 Newfoundland & Labrador Hydro

NL Hydro operates generation, transmission and distribution assets in the province, providing reliable service to rural communities throughout Newfoundland as well as to all residential, commercial, and industrial clients in Labrador as 90% of the power required by Newfoundland Power, the primary distributor of electricity throughout the island portion of NL.

Some of the relevant activities include:

- **EV Adoption** – the utility is building a DC fast charging network with 14 stations from St. John's to Port aux Basques. With a market potential of 140,000 EV's, in addition to building charging infrastructure, NL Hydro is promoting adoption through education and rebates on home chargers and vehicles.
- **Shore Power** – at an early conceptual phase, NL Hydro is interested in capturing the potential market for selling electricity to battery powered boats. The technology itself is an early stage and there are currently regulatory hurdles to ports reselling power to berthed ships.
- **Remote Communities** – there are approximately 20 isolated communities in NL reliant on diesel power systems, ranging from 50 kW to 2MW. As connecting these communities to the larger grid has been determined infeasible, NL Hydro is investigating technical requirements (controls and storage) and working with indigenous communities and IPP's to determine the path to integration of renewables in these communities. Ramea is one community where a number of technologies have been trialed including wind and hydrogen production / generation.
- **Atlantic Clean Energy Initiative** – a federal initiative to displace coal fired generation in NS and NB. When Muskrat Falls hydroelectric plant comes online, power will be supplied; through the 900MW HVDC Labrador – Island Link (Nalcor) and the 500 MW HVDC Maritime Link (Emera) from NL to Cape Breton; to NS displacing existing coal fired generation. NL Hydro is also investigating HVDC implemented on smaller projects in the North Sea, for supplying offshore rigs.

5.3.2 Emera NL

Emera NL is a holding company for the Maritime Link project and NSP Maritime Link Inc. (NSPML) is the regulatory utility responsible for operating and maintaining the 500 MW HVDC link between NS and NL. In exchange for building the project, Emera gets a firm block of energy from Muskrat Falls, about 150 MW – to offset one coal unit in NS.

Since the project was built in 2018, energy transfers are mostly from NS to NL, in order to offset diesel powered electricity from Holyrood required for peaking.

There is a potential to complete the other side of the Maritime Loop through Quebec to New Brunswick. This would open up a large opportunity to increase capacity in NL through additional hydro and / or wind (on or offshore).

06
Atlantic Canada Cleantech Ecosystem Mapping

NEIA / Noia Clean Technology Landscape

HATCH

6. Atlantic Canada Cleantech Ecosystem Mapping

The following section summarizes the mapping of the key challenges and potential solutions to the capabilities of Tier-1 contractors, private sector companies and R&D activities of post-secondary institutions R&D activities in a concise table format. Each table contains an extract of key information from the different sections in the report:

1	Key challenges and Challenge solutions (Section 3.2)
2	Tier-1 capabilities in Section 3.1.2
3	Private sector companies' capabilities in Section 5.2
4	Post-Secondary Institution R&D and Centre of Excellence in Section 4.2

The intensity of activities or supply chain support from each group can be inferred from the number of companies in the group. In addition, there are overlapping companies who have common solutions to address the different challenges.

A high-level summary analyzing the strengths of the ecosystem and extent or evidence of collaboration is included after each table.

6.1 Challenge 1: Environmental Sensing, Monitoring and Characterization

The challenge is to characterize the key ocean environment elements in order to establish a baseline environment state and to continue monitoring the impact of surrounding offshore activities.

In the area of sensing, remote monitoring and characterization, there is a robust ecosystem from both private companies and post-secondary institutions to address this challenge. Some of the Tier-1 contraction present in Canada also have similar offerings from their global products and services portfolio. There is very little evidence of strong collaborative between Tier-1 contractors and the private sector/post-secondary ecosystem. There is however evidence of post-secondary/private sector companies supporting to address this challenge via direct R&D funding from operators through PRNL. OceanVision™ is one such example where Kraken Robotics and Equinor are working on together with PRNL as intermediary. This project is focused on the development of new marine technologies and products to enable an underwater robotics data acquisition and data analytics as a service business for ultra-high-definition seafloor imaging, mapping and analytics, including simultaneous acquisition of ocean environmental and marine habitat data.

Table 6-1: Challenge 1 – Environmental Sensing, Monitoring and Characterization Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Advanced sensing and Imaging (e.g. Satellite) of iceberg, sea state/seabed, marine ecosystem, and climate** • **Digital twinning and simulation of environment** • **Subsea drones** • **Robotics**	**Aker Solutions** • Digital twin platform ix3™ **SNC Lavalin** • Geospatial, GIS, geomatics survey with CIRRUSinsite™ • Autonomous vehicle (e.g. drone) inspections **Wood** • Metocean Characterization • ENVision offering real-time emissions monitoring data management and insight **TechnipFMC** • Subsea Robotics and ROV: Gemini	• **C-Core** (iceberg) • **eDNAtec** (DNA characterization of hydrocarbons) • **GRi Simulations** – Virtual Training Simulation • **Rutter** (radar image processing) • **Kraken Robotics** • **Edgewise** – Marine mammal/Seabird observation and Acoustic monitoring • **Pangeo** – Geophysical/geotechnical service and survey • **SubC Imaging** – Subsea Camera solution • **3D Planeta** – 3D image fusion and visualization, Navec™ • **RPM Aerial Services** – Unmanned Aerial technology (RPAS) • **Ocean Sonics** – Seismic Surveys, pipeline leak detection and underwater acoustic-based monitoring • **Compusult** – Geospatial Interoperability • **Altomaxx** – Aerial Inspection and Mapping • **+ Others** – Green Imaging Technologies, Spiri Robotics, Pro-Oceanus, Dartmouth Ocean Technologies, Xeos, JASCO	**MUN** • AOSL Lab • HERF • Marine Institute **OFI** • Monitoring and analytics **UNB** • Ocean Mapping Group

6.2 Challenge 2: Production Efficiency Optimization

The challenge is to optimize the usage of key utilities such as chemicals, fuel required for cooling and heating as well as for power generation aboard the platform for potential increased of production. This also includes the more effective personnel training to implement production efficiency.

In general, this challenge often occurs asset-wide where multi-disciplinary capabilities such as those found in most Tier-1 contractors are required. Tier-1 contractors are therefore well-placed to address this with their access to global SMEs and experience. There are some specialized capabilities within the university such as reservoir production stimulation with MUN Hibernia Enhanced Oil Recovery Lab. Post secondary institutions are also offering relevant research in big data and cyber security to support the needs for data analytics and security when improving efficiency through automation. Two notable private sector companies, Virtual Marine and GRi offers advanced virtual operator training and simulation in a digital twin for operators to improve response to different production efficiency scenarios.

Table 6-2: Challenge 2 - Production Efficiency Optimization Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Digitalization** • **Integrated Digital Twin and simulation with ocean environment** • **Process Automation Technology** • **Big-data analytics** • **Machine Learning and Artificial Intelligence** • **Real time emissions tracking** • **Enhanced Oil Recovery (EOR) Research** • **Cybersecurity**	**Aker Solutions** • Digital twin platform ix3™ **Wood** • ENVision offering real-time emissions monitoring • Virtuoso® Optimization tool **Hatch** • Full suite of digital services including PAT, data analytics, digital twin, cyber security, etc. • Process Efficiency and Energy Optimization **SNC-Lavalin** • Digital Twins, real time remote operation controls of facilities **TechnipFMC** • Digital Service, Cybersecurity	• **Virtual Marine** (simulation) • **GRi Simulation**	**MUN** • Hibernia Enhanced Oil Recovery Lab • Marine Institute – simulation, offshore safety and training. **DAL** • Ocean Engineering **UNB** • Canadian Institute of Cyber Security **OFI** • Big data management and analytics

6.3 Challenge 3: Gas Turbine Emissions Reduction and Machinery Electrification

The challenge is to reduce emissions from fossil-fuel powered turbine at offshore oil and gas installations.

There are strong capabilities across the Tier-1 contractors for electrification from renewables source onshore (Hydro) and offshore (floating wind) to meet the challenge of reducing gas turbine emissions through the use of green energy as these projects typically require a multi-disciplinary team to implement. Significant capability in the region can be found with respect to electrification.

Supports from the private sectors ranges from harsh environmental characterization capability of C-Core to de-risk iceberg impacts for offshore floating renewable structures to subsea power cables and smart grid systems. Post secondary institutions research in renewable energy storage systems, smart grid and SMR will address the future distribution and renewables, storage systems, smart grid and SMR will address the challenges of a low carbon energy supply of the future.

While the region is not short of Tier-1 contractors and private sectors companies with the experience and capabilities necessary to electrify the offshore oil and gas activities, the more challenging question is the replacement of an existing system burning readily available natural gas, with the relatively high capital costs associated with supplying electricity from alternative sources. This, coupled with the need to dispose of the fuel gas when the compression trains are at capacity will require further study to determine an economic path forward.

Table 6-3: Challenge 3 - Gas Turbine Emissions Reduction and Machinery Electrification Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers / Utilities	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Long distance electrification technology (subsea cables, risers)** • **Gas Monetization of unused fuel (reinjection, H_2 production, subsea compression system, etc.)** • **Renewables Energy source + Storage (Battery) Technology** • **Iceberg management** • **Post-combustion carbon capture** • **Geological mapping of suitable reservoir for CO_2 sequestration and storage** • **Enhanced Oil Recovery (EOR) Research**	**Aker Solutions** • Electrification from shore solutions • Aker Carbon Capture: Just Catch™, Offshore Just Catch™, Big Catch, Mobile Test, CO_2 for EOR • Subsea Compression System and power distribution • Offshore Floating Wind **DNVGL** • Offshore Wind and Carbon Capture Risk Management **IINTECSEA** • Floating Wind Farms • Subsea Power Transmission Line • Floating and Subsea Substation **SNC Lavalin** • Offshore floating windfarm • End-to-end solutions for battery energy storage, Liquid Air and Compressed Air Energy Storage **TechnipFMC** • Deep Purple™ - combined offshore wind power and green hydrogen subsea production and storage and transport pressurized green hydrogen, deliver hydrogen to consumers at sea or export via pipeline. • 50+ Carbon Capture installation experience • Iceberg impact simulation, Ice-MAS. • Green Hydrogen with McPhy **Hatch** • Electrification (equipment, vehicles, processes) • CCUS (Capture, Utilization, Transportation and Storage) • Fuel Switch (natural gas, hydrogen, biomass/biofuel) **NL Hydro** • Provision of clean electricity through ports • Long distance / subsea HVDC transmission **Emera** • Long distance / subsea HVDC transmission	• **C-Core** for iceberg management on renewable infrastructure • **Greenpowerlabs** – SMART Grid • **Fundy Ocean Research Centre for Energy (FORCE)** – Tidal • **DP Energy** – Tidal and wave • **RtTech** – Equipment downtime tracking software • **Atlantic Combustion Technologies** – Biomass to Energy • **Aspin Kemp Associates** – Marine Vessel Hybridization, Microgrid • **Solace** – Pneumatic devices to Electrification • **CarbonCure** – CO_2 disposal by injecting into concrete • **Brezo Energy** – Developing new floating wind power for offshore wind farms • **Moltex** – SMR • **ARC** - SMR	**MUN** • EOR Lab **DAL** • Renewable Energy • Energy Storage **UNB** • Smart Grid • Nuclear - SMR

6.4 Challenge 4: Flaring Reduction and Recovery

The challenge is to reduce and/or eliminate planned operation and production flaring from offshore oil and gas installations.

In general, flaring recovery design is a process system designed offered by major Tier-1 contractors. Many Tier-1 contractors also offers optimization of one process equipment (esp. compression train) or the larger system, to increase equipment availability, thus reducing shutdowns and flaring. Limited information from Post-secondary Institutions can be found to support innovation in this area. A handful of private sector companies involved in flaring reduction directly through digitalized valve leakage detection such as Score (Canada) and a simultaneously operated winching system without the need for well shutdown and flaring (Axess Baffin – ALPA). No evidence of ecosystem wide collaboration was evident

The challenge of installing a brownfield flare recovery system is the availability of offshore platform real estate and the additional power requirement to compress and route the gas back to the high-pressure system. More recent flare recovery systems have been based on ejector system with lower maintenance requirements and no running coast.

Table 6-4: Challenge 4: Flaring Reduction and Recovery Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Flare recovery system technology** • **Post-combustion Carbon Capture** • **Valve leakage detection technology** • **Predictive maintenance to improve equipment availability**	**Most major tier-1 contractors have the capability to design bespoke flare recovery system. The list below highlights capabilities of Tier-1 in improving equipment availability to reduce flaring** **Aker Solutions** • Asset Integrity Management • Aker Carbon Capture: Just Catch™, Offshore Just Catch™, Big Catch, Mobile Test, CO_2 for EOR **TechnipFMC** • iLOF™ for condition-based maintenance **Hatch** • Digital twinning, predictive maintenance of compressor chain. **Wood** • Virtuoso® Asset Performance Management (APM)	• **VELAN Valve** – Improve valve control to reduce emissions • **Axess Baffin** – ALPA double retention winching system, inherently safe design to increase uptime and reduce flaring during lifting over wellhead. • **Score (Canada)** – Intelligent valve management ™ to detect valve leakage and lower emission such as flaring • **Aspin Kemp Associates** – Improved systems fault detection and increase availability	**MUN** • C-RISE

6.5 Challenge 5: Hazardous Offshore Discharges and Disposal

The challenge is to treat hazardous and contaminated by-products (Cuttings, produced water, Wastewater, etc.) from offshore activities before discharging overboard from marine vessels (supply, transportation, installation, etc.) and the production/drilling platform.

There appears to be very little support in the ecosystem when it comes to treatment or services relating to hazardous discharges from oil and gas production. None of the tier-1 contractors have mentioned such capabilities other than Halliburton and Lloyd's Register in the area of drilling oil/water/cutting treatment and hazardous material during decommissioning. In general, most Tier-1 contractors will design and procure a treatment package from global vendors. This is also evident in the number of private sectors where only a handful of companies were identified as potentially suitable in supporting cleantech in offshore oil and gas.

As the offshore assets age and water breakthrough increases, coupled with increasingly stringent environmental regulation, produced water treatment is increasingly important. As exploration ramps up in the offshore, improved treatment of drill cuttings and environmentally friendly drilling fluid will be key in addressing disposal of such wastes.

Table 6-5: Challenge 5: Hazardous Offshore Discharges and Disposal Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Innovative treatment process of removal of hazardous substance (hydrocarbon)** • **Use of cleaner oil as lubricants for drilling activities**	**Halliburton** • Oilfield water management • Baroid Separation Solution: Offshore in-situ drill cuttings treatment to reduce oil-on-cuttings (OOC) for overboard disposal **Lloyd's Register** • Mitigation advisory of hazardous material during decommissioning or life extension program	• **LuminUltra** – microbial testing of PW • **Evoqua Water Technologies for oil removal** • **Oil Filtration Solutions (OFS)** • **Terrapure Environmental** – Battery and Oil recycling solutions • **Sustane** – Transforming municipal solid waste to raw materials	**MUN** **DAL** • Centre for Water Resource Studies

6.6 Challenge 6: Oil Spill Emergency Response

The challenge is to provide an effective oil spill detection, mitigation and efficient intervention with minimum risk.

There is a robust ecosystem within the region to address this challenge. A number of private sector companies are involved already in the detection and mitigation of oil spills. From an innovation perspective, key players are Rutter and C-Core where new detection, and recovery technology are being developed respectively. MUN's NRPOP Lab is prominent in a multi-partner effort aimed at improving knowledge of how oil spills behave, how to contain them, clean them up and minimize their environmental impact. There is limited evidence of wider and more specific collaboration other than the one between CNA and Rutter on radar-based oil spill detection and between NRPOP, various regional environmental association (e.g. NEIA, etc.) and oil spill experts both in Canada and worldwide on improving knowledge of how oil spills behave, how to contain them, clean them up and minimize impacts.

Table 6-6: Challenge 6: Oil Spill Emergency Response Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private sector companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Advanced sensing to detect oil spill** • **Advanced dispersants** • **Digital twin and simulation for virtual reality emergency response training**	**DNVGL:** • Oil spill risk assessment and response planning modelling	• **ECRC** – administers Offshore oil spill preparedness program on behalf of operators **Detection and Mitigation** • eDNAtec • Rutter – radar detection • C-Core – Mechanical recovery and oil spill response • Hi-Point Industries – Oil absorbents technology • Provincial Aerospace – Environmental Surveillance Service • Nord Marine – Containment kits, booms, etc. • Pro-Oceanus – Dissolved gas sensors for well blow-out spills • Xeos – Oil spill surface tracker (OSKER, ROBY) **Training for Response** • Virtual Marine, GRi Simulation, Nord Marine	**MUN** • AOSL • NRPOP Lab **OFI** **CAN** • Radar Detection w/Rutter

6.7 Challenge 7: Logistics Optimization

The challenge is to reduce emissions by managing logistics transportation (such as marine, helicopter) with optimization of scheduling, transport (design, type and size), fuel type used and personnel/cargo load.

Logistics optimization requires a system's approach which is a common service offering among the Tier-1 contractors. However, many innovations ranging from digitalization to hybrid-powered vessels are global corporate initiative and very few are Atlantic Canada-based. There are a number of regional companies specializing in streamlining workplaces and/or logistics and marine vessel design companies capable of optimizing the next generation of vessels. More notably some are focusing on vessel-free intervention and installation method (flare tip replacement by AxxesBaffin) and battery-powered Crude Oil Tanker (battery-based by Altera).

There is little evidence of research activity in post-secondary institutions surrounding general logistics optimization, but it is apparent that most research is targeted on more specific areas of vessel design and alternative fuel use. Universities like MUN and its Marine Institute offers degree courses such as the Masters in Maritime Management to provide the provide the skills and knowledge necessary to manage the diversity of marine operations. However, there is little evidence of collaboration of any kind between the ecosystem specifically in cleantech.

A notable initiative undertaken by a Tier-1 company is the Lloyd's Register Foundation which provides funding for projects which fit its mission statement "…enhancing the safety of life and property at sea…", which certainly meets the criteria of cleantech.

Table 6-7: Challenge 7: Logistics Optimization Ecosystem in Atlantic Canada

Challenge Solution	Tier1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Complex logistics data analytics and optimization routine** • **Integrated scheduling and tracking of goods and personnel transport** • **Innovative marine vessel propulsion systems** • **Innovation in ship hull design and advanced drag-reducing coating**	**Hatch** • HxO Scheduling and logistics optimization **Lloyd's Register** • Digitalization in operation to reduce manning, fewer helicopter flights, less material transfer • Digital Twin to monitor hull integrity when positioning FPSO to reduce maintenance requirement • Hull coating to reduce drag and improve fuel efficiency with real time monitoring • Fuel Monitoring and Analytics application to help them to identify ways of reducing fuel consumption through the power of data enabled marine vessel. • Wind-assist Flattner Rotor propulsion. • Establishment of Poseidon principle to assess future risk of vessels not meeting emissions standards **SNC Lavalin** • Cold Climate Logistics with short shipping windows **TechnipFMC** • Subsea 2.0 aims to simplify equipment by reducing weight, size and part count by 50% • Hybrid powered diving support and heavy construction vessel, Deep Arctic (2021) • Biofuel in Marine Vessel **Wood** • Real time monitoring and analytics to provide decision making support for logistics, POB reduction in offshore installations.	• **AxessBaffin** – Mechanical flare tip replacement solutions (vs. helicopter) • **Genoa Design** – 3D modeling to shipbuilding from concept to decommissioning • **Cougar Helicopters** • **Altera Infrastructure** – E-shuttles – Crude oil tanker with battery-powered, LNG as fuel with onboard VOC • **ASCO Canada** – Digital twin of offshore supply base to increase efficiency • **Focus FS** – Software for safer, efficient worksites, streamlining equipment management • **Blue Water Group** – Supply Logistics • **Atlantic Towing** – Hybrid battery-diesel-electric propulsion Platform Supply Vessel • **SkyHawk Telematics** • **Mara Renewables** – Algae-based biofuel • **Brezo Energy** – Ship design • **Dominion Diving** – Customized integrated logistics and transportation service • **McKeil Marine** – Logistic studies • **Duxion Motors** – Hybrid Marine Propulsion System • **Redrock Power Systems** – Hydrogen Fuel Cell/Battery System for Marine	• **MUN** (School of Maritime Studies degree course on Maritime management) • **DAL** (Dalhousie Battery Research)

6.8 Challenge 8: Remote and Integrated Operations

The challenge is to reduce the requirement for continual personnel presence at operating sites offshore through greater automation and the establishment of reliable process monitoring and control centres at safe remote locations.

The concept of integrated operation is usually a holistic approach requiring a large team to provide service on different operation level. Such service offerings are mostly provided by Tier-1 contractors as evidenced by the strong products and services available. On the more specific level of integrated operations, of which remote operations are a part, there is a strong ecosystem of private sector companies with ROV-based capabilities to survey the environment (C-Core, SubC Imaging, etc.) carry out inspection, maintenance using subsea UAVs (Kraken, RPM, etc.), remote risk-free training (Virtual Marine) all of which are supported by academia through facilities such as MUN's AOSL Lab. Ecosystem collaboration has started and is expected to ramp up significantly with the Digital Offshore Canada project, funded by the Ocean Supercluster and PRNL, with the involvement of Operators, Tier-1 contractors (Hatch), key local private companies (GRi, Virtual Marine, MNP) and MUN.

Table 6-8: Challenge 8: Remote and Integrated Operations Ecosystem in Atlantic Canada

Challenge Solution	Tier-1 Suppliers	Private Sector Companies (See Section 5.2 for more details)	Post Secondary Institutions
• **Digitalization** • **Cyber Security** • **Digital twinning and simulation** • **Drones and Robotics**	**Aker Solutions** • Subsea intervention and remote workover riser (e.g. riserLOCK ™) • Digitalization/technology around logistics, document and people management to improve work and energy efficiency. • Unmanned FPSO Concept **Halliburton** • Digital Well Operations Solution connecting rig site workers to remote operation centres where a digital twin of the well sits. **Hatch** • Digitalization strategy/roadmapping development across Infrastructure, Mining/Metals, and Energy business sectors. • Digital twins for operational readiness and efficiency improvement • Simulation and optimization solutions across value chains for improved operating performance, asset health performance, safety of people and environment • Smart digital project delivery **SNC-Lavalin** • Remote monitoring of tools, digital twins, and real time operational controls of facilities • Facility optimisation with autonomous vehicle (e.g. drone) inspections to reduce carbon intensive remediation activities **TechnipFMC** • Subsea Integrated Maintenance and Repair (IMR) • Next Gen ROV: Gemini with improved and increased tooling, remote movement resistance to provide feedback to pilot, improved stabilisation	All companies in Challenge 1 are applicable and vice versa: • **C-Core, GRi Simulations, Kraken Robotics, Edgewise, Pangeo, SubC Imaging, 3D Planeta, RPM Aerial Services, Ocean Sonics, Virtual Marine, Altomaxx, Spiri Robotics** • **SmartICE** – advanced data acquisition and remote monitoring technology of sea ice • **Oceaneering** – A subsea connection and survey specialist • **Solace - Equus™** – Modular Wireless Power Platform. • **Focus FS** – Software for safer, efficient worksites. • **Dominion Diving** – Remotely operated underwater vehicle (ROUV) Service	**MUN** • AOSL Lab • HERF • MEDICOR – Remote patient monitoring

6.9 Mapping Summary

Strengths

- Environmental monitoring (autonomous craft, sensors, mapping, etc.) – cross sectoral – aquaculture, energy, fisheries, defence.
- Significant capability in the region with respect to electrification (renewables integration, HVDC transmission, smart grid / energy storage, etc.).
- Risk assessment, detection, characterization and mitigation of oil spills.
- Substantial capabilities in development of electric propulsion systems for boats.
- Capabilities related to advanced logistics.
- Remote operations capabilities exist in the ecosystem.

Threats

- Economic viability of cleantech solutions.
- Lack of visibility and lack of collaboration on the operator challenges.
- Exodus of talent away from the offshore oil and gas industry.

Under Representation

- Capabilities exist in the field of digitalization, however, there is potential for demand in the industry to outstrip region capacity.
- Lack of clear path to reducing CO_2 emissions from electricity generation.
- Lack of activities to support potential transition to a Hydrogen economy.

Strengths

- Support further development and collaboration in the area of environmental monitoring.
- Stimulate private sector involvement in digitalization and leverage relative strengths of the post-secondary and Tier-1 suppliers.
- Comprehensive options study to determine the best way forward for decarbonization of the power supply offshore.
- More comprehensive studies around – operational efficiency and availability of the compression train.
- Study potential pathways for monetization of natural gas.
- Support further redevelopment and collaboration in the area of oil spill response.
- Additional studies to confirm benefits and supporting further collaboration and development for electrification of vessels.
- Support wider logistics optimization for the industry as a whole
- Investigate opportunities for robotic automation within the platform operations.
- Investigate further opportunities for remote operational control and reduction of POB.
- Adoption of cleaner cutting fluids and cutting treatment facilities to allow for in-situ disposal.
- Further investigation into potential improvements in produced water management.

07
Conclusion: Priority Opportunities

NEIA / Noia Clean Technology Landscape

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7. Conclusions: Priority Opportunities

The study presents an overview of the growing pressures in the form of global and regional drivers to improve environmental performance of the activities within the offshore oil and gas industries. These drivers are closely interrelated to many of the challenges communicated by the oil and gas companies operating in the region.

It is clear from the engagement conducted with the various stakeholders' institutions and (modest) survey evidence from private businesses, there is an underlying ecosystem well-suited for cleantech innovations to address these challenges.

Some ecosystems are more robust than others in terms of products and services offering and collaborative initiative. Many of the ingredients for a stronger innovation eco-system for oil and gas already exists in Atlantic Canada, including industrial associations such as Noia and NEIA who have a critical role to play at the centre of the sectors' cleantech future.

Key Findings of the study in terms of the roles by different business groups in addressing the challenges are:

1	All operators are engaged in some cleantech innovations at a corporate level as well as ecosystem wide collaboration when addressing the challenges. Some more so than the others. Common themes among the operators are GHG reduction through process efficiency optimization, renewables energy sources and remote operations where it makes economical sense.
2	Tier-1 contractors have a full suite of corporate level products and services which could potentially address many of the challenges.
3	Post-secondary institutions offer undergraduate and graduate degree courses, some with direct application in providing solutions to address these challenges. The various specialized labs and facilities at these institutions, such as the Harsh Environment Research Facility (HERF) and Enhanced Oil Recovery (EOR) lab at Memorial University are well equipped to carry out innovative research in cleantech.
4	Private local businesses already engaged in cleantech innovation tend to be working in the fields of remote sensing, environmental characterization and oil spill detection with robotics and subsea drone. Other notable areas where cleantech innovations occur are in the fields of logistics and oil spill response.

Key conclusions from the Mapping and Gapping for each challenge are:

1	There is a strong ecosystem when it comes to addressing the challenge of environmental sensing/monitoring and characterization, oil spill response, logistics optimization and remote operation. This is not surprising as these challenges require local knowledge and are, therefore, well-suited to businesses where there is local presence.
2	In the challenge area of production efficiency optimization, system-wide knowledge of production assets is key to providing such services and relevant knowledge generally resides within Tier-1 contractors. Digitalization will play a key role in solving this challenge and there exists capabilities to support it, within the region; however, there is potential for demand in the industry to outstrip capacity.
3	In the challenge area of gas turbine emissions reduction where proprietary technology is often used, efficiency optimization efforts are often referred to the OEM which is normally managed through Tier-1 contractors. Emission reduction is also often achieved through a more system-wide aiming at operational efficiency to reduce energy consumption. This undertaking resides mostly with Tier-1 contractors who have asset-wide knowledge. Emissions reduction through carbon capture and sequestration (CCS) technology appears to be under-represented regionally although significant research on CO_2-EOR has been carried by MUN. Apart from that, significant capability in the region can also be found with respect to electrification from shore ranging from Tier-1 multi-disciplinary project capability for offshore cable installations as well as regional private companies experience from electrical grid distribution from hydropower.
4	In the challenge area of Flaring Reduction and Recovery, a system-wide understanding is required, thus the involvement of which Tier-1 contractors. There are therefore very few private sector companies which have capability in this area. Currently, there is very little post-secondary research in this area. No evidence of ecosystem wide collaboration is observed.
5	In the challenge area of hazardous offshore discharge disposal, there are a handful of water treatment companies in the private sectors with capability along with some post-secondary activity. No evidence of ecosystem wide collaboration is observed.
6	One area that potentially could play a role in the future is the development of hydrogen economy. This topic appears to be under-represented with respect to activities and capabilities within the region.

08
Recommendations: Actions to Prioritize

NEIA / Noia Clean Technology Landscape

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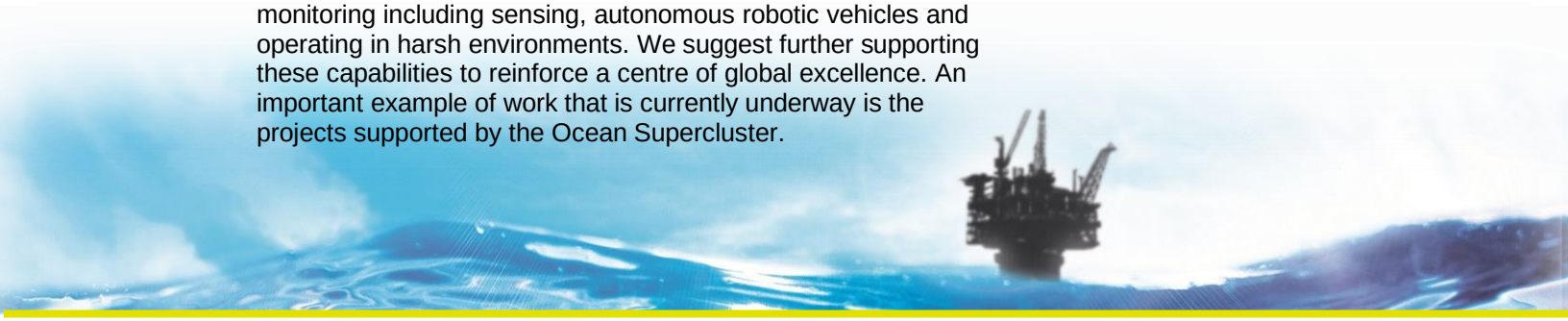
8. Recommendations: Actions to Prioritize

8.1 Specific Activities

Significant strengths were identified in the area of environmental monitoring including sensing, autonomous robotic vehicles and operating in harsh environments. We suggest further supporting these capabilities to reinforce a centre of global excellence. An important example of work that is currently underway is the projects supported by the Ocean Supercluster.



Recent oil spill events reinforce the importance of a robust capability in the area of monitoring, sensing and characterization to aid mitigation and emergency response. Given the emerging developments to improve these capabilities, we recommend continuing support of, and encouraging collaboration across, the ecosystem.

We recommend continuing to stimulate private sector involvement in the digitalization of the offshore and reinforce ties with the post-secondary institutions and Tier-1 suppliers in order to build further capacity and meet the growing demand. Solutions encompass remote operations for reduced POB, digital twinning for improved operational efficiency and robotic automation for remote inspection and maintenance activities. Notably, the growing high-tech industry in the region speaks to the significant capabilities available to the industry.

Alongside the existing and ever-growing regional strengths in environmental monitoring, sensing and autonomous robotic vehicles, continued support for digitalization should help to grow the region's capacity to better respond to the net zero commitments of operators and governments.

A significant source of CO_2 emissions involves both the transportation of materials and personnel to and from the offshore production and drilling platforms as well as the transportation of crude oil from production site to shore. There are potential opportunities to improve this logistics through even more integrated coordination, digitalization of operations and hybridization of propulsion systems. Capability exists in the region in all aspects; however, continued support and coordination would improve the environmental performance of these activities.

The current power supply on the offshore platforms fueled by natural gas represents about 70% of total GHG emissions making this one of the most important challenges to solve. Solutions have been proposed, including electrification from shore, integration of local renewables and carbon capture and sequestration from post-combustion emissions. A comprehensive options study is recommended to determine a viable path forward. This may also consider potential pathways for monetization of the produced natural gas.

Advocate for regulatory alignment and economic incentive to ensure best available technology is adopted for key environmental impact activities such as drill cutting disposal and produced water. For example, advanced drilling lubricants exist that are less impactful on the environment, but which are not used due to cost.

8.2 Other Considerations

Cutting across the Challenges identified in the study, the Oil & Gas Sector in Atlantic Canada should look more generally at the underlying eco-system for innovation. It is clear from the (modest) survey evidence that, although there is a base of cleantech innovation activity already in place the region, there is scope to do more. Companies that are already engaged in cleantech

innovation are generally positive about the experience and those that have not yet engaged have indicated that they could be assisted to get involved if certain factors are addressed. There is a thread running through the evidence that suggests there may be scope for a broadly cast intervention in the sector to better share intelligence on the current and future projected requirements of the oil and gas sector. This would include:

- Helping upper tier businesses better articulate their expected demands to help smaller businesses and Tier-1 companies better support their transition
- More foresight on the impacts and implication of government regulations to help stimulate new innovative thinking within the sector and unlock investment in new facilities and processes
- Scope for businesses and institutions to better understand each other's capacities and priorities in order to facilitate more collaboration on shared challenges
- Additional understanding of the global drivers of change in the sector and the innovative best practices being deployed elsewhere in the oil and gas and other sectors that could be deployed in Atlantic Canada
- And a strong voice to articulate the strengths and challenges facing the oil and gas sector in Atlantic Canada to the wider global sector and to provincial and national government.

Many of the ingredients for a stronger innovation eco-system for oil and gas already exist in Atlantic Canada, including intermediaries such as Noia and NEIA who have a critical role to play at the centre of the sectors' cleantech future.

The core objective of a stronger eco-system for cleantech innovation is to create a stronger appetite for collaborative innovation which brings together government bodies, higher education institutions, oil and gas operators, Tier-1 companies and the vital wider supply chain. Success will be best achieved by developing a stronger shared understanding of the sector's strengths and assets, as well as its weaknesses. This report provides a base on which to build but further work is needed to maintain a rigorous base of insight and to facilitate the necessary collaborations upon which successful innovation will likely rest. Lessons can be learned from other sectors that have adapted to new drivers of change such as the aerospace sector where top-down command and control supply chain relationships are evolving into more collaborative co-creation of solutions around shared cross-sector challenges.

Alongside building a stronger appetite for collaborative and firmer relationships between sector players, the oil and gas sector will continue to require ongoing investment in:

Assets	To replace outdated on shore and offshore facilities
Skills	To upgrade and refresh the know how among the workforce and to attract new talent
R&D	To establish new solutions to the emerging challenges facing the sector and to secure a sustaining capacity to generate new intellectual property solutions from within Atlantic Canada.

The proposed Innovation Centre being developed by techNL (formerly NATI) will provide additional capacity and potentially create a focal point for the sector to come together to address its shared challenges. The upcoming business planning exercises to set out its key activities, programs, and a governance model should build on the insights generated in this report and flesh out a clear plan of action to broadly strengthen the eco-systems and support specific programmes of innovation, investment and skills development.

09
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Appendix A
Engagement Methodology

NEIA / Noia Clean Technology Landscape

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Appendix A: Engagement Methodology

A.1 Overview

A systematic approach (as shown in Figure A1-1) was used to carry out a thematic research of the cleantech innovation landscape in Atlantic Canada in response to the eight challenges of the offshore oil and gas industries identified.

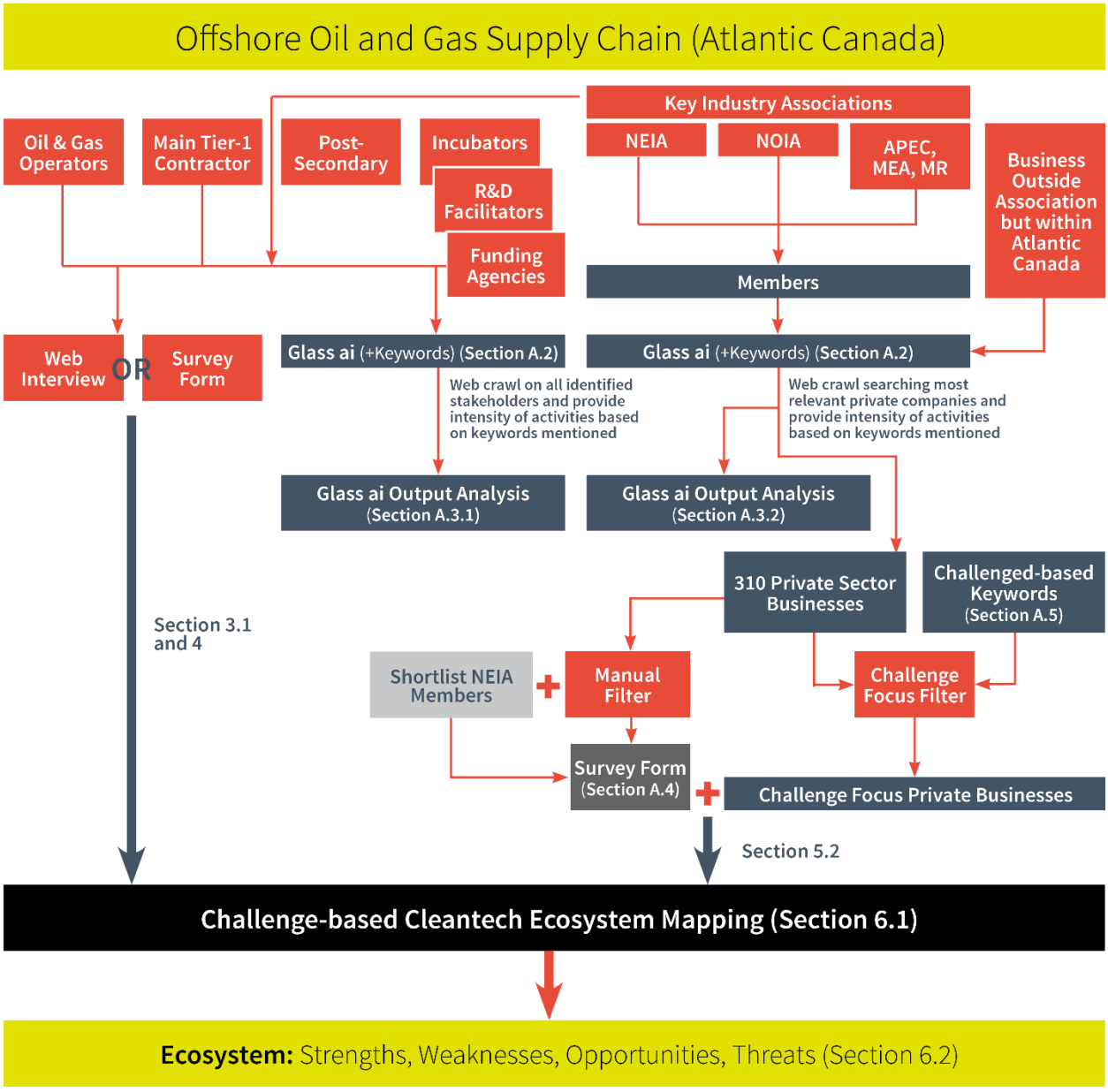


Figure A1-1: Systematic Approach for Thematic Research of Atlantic Canada Cleantech Landscape

A list of organizations and businesses consisting of the following ecosystem within Atlantic Canada was created:

1	Oil and Gas Operators
2	Main Tier-1 Contractors
3	Post-Secondary Institutions
4	Incubators
5	R&D Facilitator
6	Funding Agencies
7	Industry Associations (NEIA, Noia, NATI, MEA, MR, APEC, etc.)

All the above organizations/businesses were engaged to provide feedback on cleantech innovation in their organizations via a web interview or online survey. The web interview was conducted using a set of questions specific to the organization they represent. These set of questions are detailed in Appendix A.4 with prime focus of understanding their capabilities and capacities in relation to cleantech for the offshore oil and gas industries. Such information collected from the web interview and online survey for this group of organizations/businesses formed the contents in Section 3 and 4.

Each organization was also subjected to a web crawl using Glass ai to provide an overview of intensities of cleantech activities based on cleantech keywords as described in Appendix A.2. The results were then analysed and presented in Appendix A.3.1.

In addition, members from within the industry associations and additional Atlantic Canada-based businesses outside those associations were also subjected to the same web crawl using Glass ai to provide an overview of intensities of cleantech activities based on cleantech keywords as described in Appendix A.2. A short list of 310 private sector companies were shortlisted as most relevant to the cleantech space as defined by the keyword themes. The results were then analysed and presented in Appendix A.3.2.

The shortlist of 310 private sector companies were subsequently filtered manually to about 230. Together with a shortlist from 40 NEIA members and cursory mention of 9 from the web interview, a filtered list of 279 businesses were identified. The list was further shrunk to 176 businesses as the others did not have readily available contact/email addresses. The 176 business were then sent an online survey with a set of questions detailed in Appendix A.4 under private sectors. The results of the online survey were analysed and presented in Section 5.1.

As the responses to the survey were relatively few and far between, the 310 private sector businesses from Glass ai was subjected to a secondary filter with offshore oil and gas industries challenge-specific keywords search (as described in Appendix A.5) within the evidence of each business. A set of companies were extracted based on their activities defined by specific keywords associated with the challenge. This is presented in Section 5.2.

The capabilities of Tier-1 contractors (Section 3), private businesses (Section 5.2) and Post-secondary institutions were then grouped together to form eight different ecosystems, each one addressing one challenge. These are detailed in Section 6. Additional companies were also added based on NEIA's suggestion. Subsequently, the cleantech landscape is completed in Section 6.9 with an overall SWOT analysis highlighting the strengths, gaps, opportunities and threats of the Atlantic Canada ecosystem in relation to the cleantech for the offshore oil and gas industries.

A.2 Glass ai Methodology

Glass ai uses web crawling technology to identify and read the websites of Atlantic Canada organizations/businesses and query the cleantech activities of each organization/business using a set of keywords relevant to cleantech such as renewables, wastewater treatment, etc.

Glass ai technology augment the search accuracy by cross-referencing with data sources like news, social media, academic and official data associated with the business.

A.2.1 Input to Glass ai

Glass ai was provided with a list of key stakeholders consisting of the following:

1	Oil and Gas Operators
2	Post-Secondary Associations
3	Industrial Associations
4	Funding Agencies
5	Incubators
6	R&S Facilitators

A table of 116 keywords relevant to the cleantech sectors were also provided as shown in Table A2-1 alongside a high-level taxonomy classifying the keyword under four broad categories of cleantech theme of

1	Reduction of GHG Emissions (CC)
2	Clean Energy & Energy Efficiency (CEEE)
3	Environmental Impact Performance & Sustainability (EPS)
4	Environmental Characterization and Monitoring (ECM)

Table A2-1: Keywords for Glass ai Webcrawl and Corresponding Cleantech Theme

No.	Keywords for Glass ai Web Crawl	Clean Tech Theme
1	Advanced Materials	EPS
2	Alternative Fuel	CEEE
6	Bioenergy	CEEE
7	Biofuel	CEEE
8	Biomass	CEEE
9	blue hydrogen	CEEE
10	booms	EPS
11	Carbon capture	CC
12	Carbon emissions	CC
13	Carbon storage	CC
14	Carbon-neutral	CC
15	Clean energy	CEEE
16	Cogeneration	CEEE
17	combined cycle combustion	CEEE
18	dispersant	EPS
19	dispersion	EPS
20	Distributed Generation	CEEE
21	Drill mud	EPS
22	Drillcutting	EPS
23	Electric vehicle	CEEE
24	Electrification	CEEE
25	Energy efficiency	CEEE
26	Energy Management	CEEE
27	Energy storage	CEEE
28	Enhanced Oil Recovery (EOR)	CC
29	Flare Recovery	CC
30	Geothermal	CEEE
31	GHG	CC
32	Green chemistry	CEEE
33	Green energy	CEEE
34	Green transportation	CEEE
35	Green vehicle	CEEE
36	grey hydrogen	CEEE
37	Heat pump	CEEE
38	Hydroelectricity	CEEE
39	hydrogen	CEEE
40	Hydrokinetic	CEEE
41	Low carbon	CC
42	Low-carbon	CC
43	Microgeneration	CEEE
44	Microgrid	CEEE
45	Net zero	CC
46	Nuclear	CEEE
47	pilotless flaring	CC
48	Produced Water	EPS
49	Recycling	EPS
50	Remediation	EPS
51	Renewables	CEEE
52	SDG	EPS
53	skimmers	EPS
54	Small Modular Reactor	CEEE
55	Smart city	CEEE
56	Smart energy	CEEE
57	Smart grid	CEEE
58	Solar	CEEE
59	Solar energy	CEEE
60	Solar photovoltaics	CEEE
61	Super grids	CEEE
62	Sustainable Development Goals	EPS
63	Sustainable energy	EPS
64	Sustainable engineering	EPS
65	Tidal	CEEE
66	value from waste	CEEE
67	Waste	EPS
68	Wastewater	EPS
69	wastewater	EPS
70	Wave	CEEE
71	Wind	CEEE
72	Wind energy	CEEE
73	Wind power	CEEE
74	anthropogenic noise	EPS
75	biodiversity	EPS
76	Characterization and monitoring	EPS
77	edna	EPS
78	Emission Monitoring	EPS
79	Environmental Impact	EPS
80	environmental characterization	ECM
81	environmental effects	EPS
82	environmental genomics	ECM
83	environmental monitoring	EPS
84	Environmental science	ECM
85	environmental sensing	ECM
86	Environmental technology	ECM
87	ice	ECM
88	iceberg	ECM
89	Leak Detection and Repair (LDAR)	EPS
90	oil spill	EPS
91	Oil Spill Detection	EPS
92	Oil Spill management	EPS
93	oil spill response	EPS
94	Pollution	EPS
95	real-time	EPS
96	sea states	ECM
97	seabed mapping	ECM
98	seabed sampling	EPS
99	seabirds	EPS
100	whales	EPS
101	Risk mitigation	EPS
102	subsea	EPS
103	Zero plastic	EPS
104	Remote	CEEE
105	battery	CEEE
106	Predictive analytics	CEEE
107	Scheduling	CEEE
108	Logistics	CEEE
109	Transportation	CEEE
110	Marine Vessels	CEEE
111	CCS	CC
112	Digitalization	All
113	Drone	ECM
114	Robotics	ECM
115	Artificial Intelligence	CEEE
116	Digital Twin	ECM
117	Simulator	ECM

A.2.2 Glass ai Raw Output

Glass ai raw output for each organization/business consists of the following data fields:

1. **Organization Name** – name of the business as it appears on the website.
2. **Website** – URL for the business.
3. **Description(s)** – textual data pertaining to the type of economic activity conducted by the business extracted from the website (usually from the company description).
4. **Sector(s)** – predicted sectors for the companies by the glass.ai engine.
5. **Location, Postcode** – details of the main trading address.
6. **Cleantech Evidence** – indicator(s) of the organization cleantech activity based on the keywords and counts of the keywords mentioned aggregated to one of the four cleantech theme listed in Section A.1.1 to gauge the intensity of the activity.
7. **Official Data Matching** – company reg. number, if available. The company incorporation date, registered name, sector code and registered address can also be provided.
8. **Social Media Matching** – links to social media accounts (Twitter, LinkedIn) available from the websites.
9. **Number of Employees** – number of staff, whenever available from sources like the website, press releases or LinkedIn (proxy for employees).

A.2.3 Stakeholder Organizations

Glass ai uses the input described in Section A.1.1 to map stakeholders' organizations with evidence of cleantech activities based on the keywords provided. Analysis of output from Glass ai on stakeholder organizations can be found in Appendix A.3.1.

A.2.4 Private Sector Business Shortlist and Targeted Survey

As well as mapping stakeholder organizations, Glass ai also mapped the wider private sector business in Atlantic Canada delivering cleantech solutions and services.

Based on the targeted webcrawl Glass ai lists a total of 310 private businesses based on key associations member lists (NEIA, Noia, NATI, APEC, ME, MR) and any additional businesses outside those organizations but have businesses in the cleantech areas identified through the cleantech keywords.

Analysis of output from Glass ai on private sector businesses can be found in Appendix A.3.2

Each of the 310 private sector businesses shortlisted was filtered manually for the most relevant businesses to be targeted for online survey.

A.3 Glass ai Output

A.3.1 Stakeholder Institutions

A.3.1.1 Overall Size & Location

Glass ai search for cleantech stakeholders found a total of 74 organizations operating in the sector in the Atlantic Canada region, which combined employ over 328,000 people globally.

Stakeholder organizations were in all four Atlantic Canada provinces, shown below.

Table A3-1: Stakeholder Organizations in Atlantic Canada

Province	Stakeholder Organizations	% of Stakeholder Cleantech Organizations
Newfoundland & Labrador	35	47%
Ontario	9	30%
Nova Scotia	22	12%
New Brunswick	6	8%
Prince Edward Island	2	3%

Source: Glass ai

Nine organizations were identified outside of the Atlantic Canada i.e., in Ontario. These organizations have substantial activity in the Atlantic Canada region and have therefore been included in this analysis.

A.3.1.2 General Sub Sectors

Standard sub-sectors have also been assigned to the organization, these have wider relevance beyond the cleantech arena. This cut of the stakeholder base shows most organizations operate within the oil and energy sub-sector followed by government agencies and other bodies, with seven higher education and five professional bodies also operating in the area.

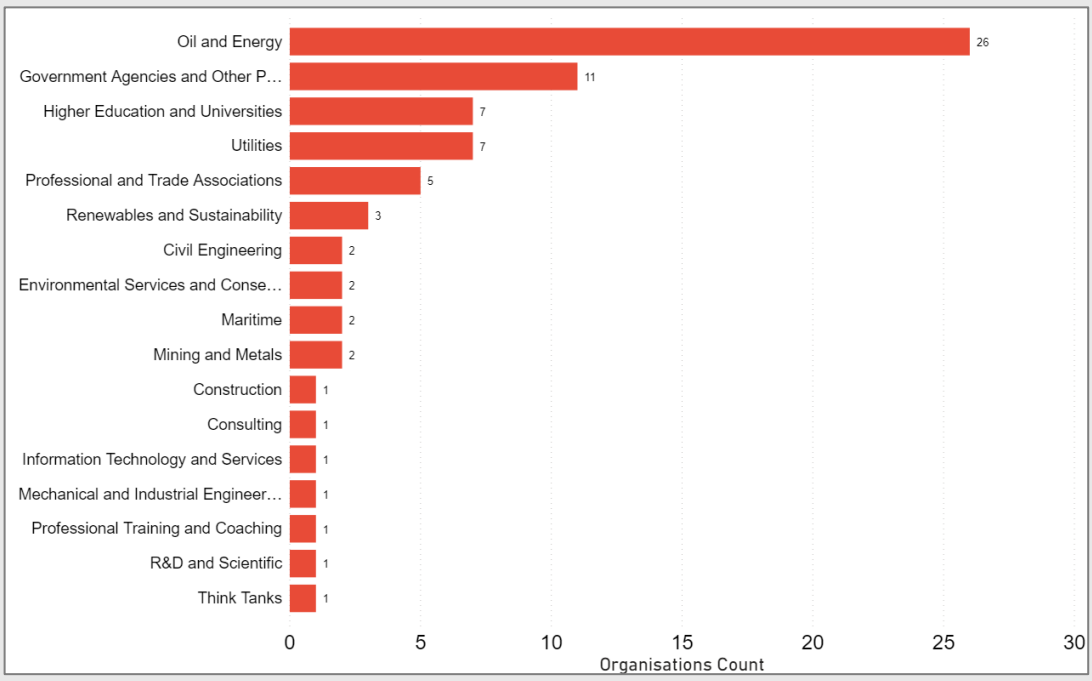


Figure A3-1: Standard Sub-sectors of Stakeholder Organizations

The five largest organizations in each sector (where possible) are shown in the table below.

Table A3-2: Organizations in Each Sector

Organizations	Employees
Civil Engineering	
SNC Lavalin	16,073
CBCL Limited	331
Construction	
Kiewit Offshore Services	n/k
Consulting	
Stantec	20,841
Environmental Services and Conservation	
Golder Associates	7,131
LGL Limited	n/k
Government Agencies and Other Public Bodies	
CRA (SR&ED)	9,702
Business Development Bank of Canada (BDC)	3,663
Export Development Canada (EDC)	2,072
Natural Resources Canada (NRCan)	2,779
Natural Sciences and Engineering Research Council of Canada (NSERC)	471
Higher Education and Universities	
Dalhousie University	6,000
College of The North Atlantic (CNA)	1,022
Memorial University (MUN)	3,740
University of New Brunswick	2,455
UPEI	850
Information Technology and Services	
DNV GL	14,524
Maritime	
Kongsberg Maritime	4,138
Maritimes Energy Association	6
Mechanical and Industrial Engineering	
Kvaerner Canada Limited	1,278
Mining and Metals	
BHP	29,354

Organizations	Employees
Hatch	7,757
Oil and Energy	
Chevron	65,994
ExxonMobil	65,223
Wood	29,997
Suncor	13,759
Husky	5,649
Professional and Trade Associations	
NL Association of Technology & Innovation (NATI / TechNL)	60
Noia	12
NEIA	4
Nova Scotia Offshore Energy Research Association (OERA)	n/k
Offshore Energy Research Association (OERA)	n/k
Professional Training and Coaching	
Genesis Centre	29
R&D and Scientific	
C-Core	99
Renewables and Sustainability	
Sustainable Development Technology Canada (SDTC)	77
Growler Energy	9
Marine Renewables Canada	1
Think Tanks	
Atlantic Provinces Economic Council (APEC)	15
Utilities	
EfficiencyOne	115
Emera	2,075
Fortis	51
Maritime Electric Company	88
Nova Scotia Power	786

A.3.1.3 Cleantech-Sub Sector Focus

The top 15 words mapped within the web presence of all stakeholder organizations are shown below. The numbers denote the number of times each keyword was mentioned on stakeholder organizations' web presence.

Table A3-3: Top 15 Keywords of Stakeholder Organizations

Keyword	Number of Keyword Mentions on Stakeholder Organizations' Web Presence
Innovation	66
Sustainable	66
Carbon	63
Wind	63
Climate Change	62
Efficiency	62
Waste	62
Climate	61
Sustainability	60
Greenhouse Gas	59
Real-Time	58
Energy Efficiency	57
Hydrogen	57
Environmental Impact	56
Ice	56

The keywords have been used to determine the cleantech sub-sectors in which the stakeholder organizations operate. We have allocated each organization to a principal cleantech subsector (i.e., the one it best fits) and secondary sub-sectors to reflect the fact that many businesses operate in more than one sub-sector.

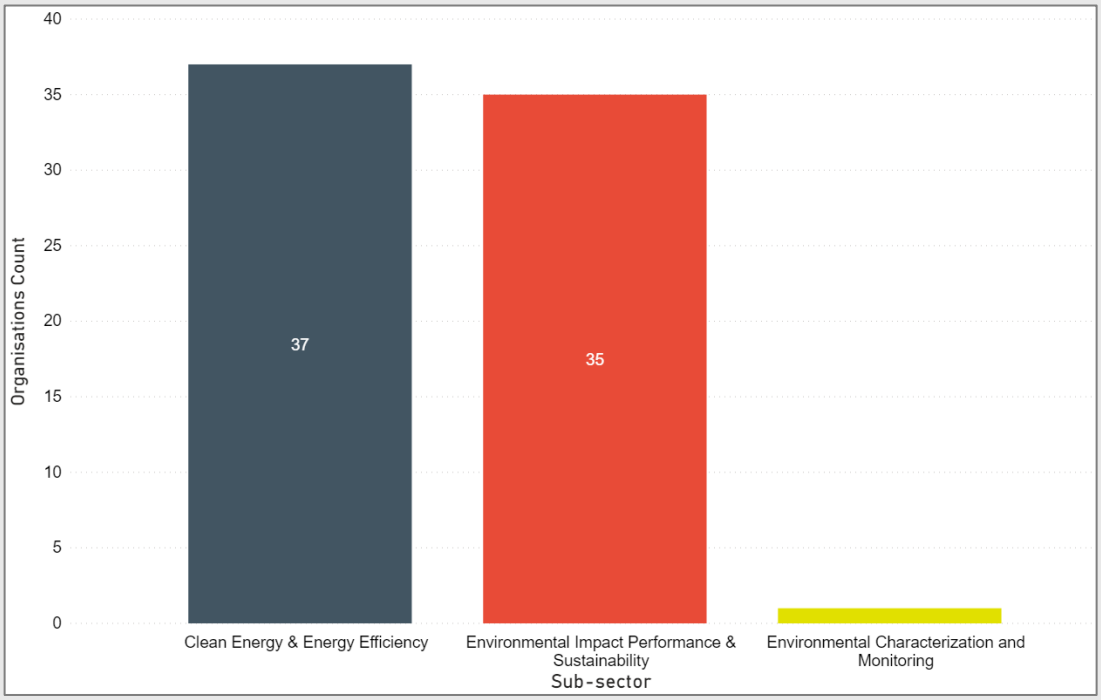


Figure A3-2: Principal Cleantech Sub-sector Operations of Stakeholder Organizations

Half the stakeholder organizations(37) operate principally in the Clean Energy & Energy Efficiency cleantech sub-sector. This is followed by the Environmental Impact Performance & Sustainability sub-sector (35), and then Environmental Characterization and Monitoring (2). No stakeholder organization operates principally within the Reduction of GHG Emissions sub-sector.

The wider analysis of organization's operations across sub-sectors provides a clearer indication of a base of organizations involved in Reduction of GHG Emissions and Environmental Characterization and Monitoring (albeit although not as their principal area of focus.

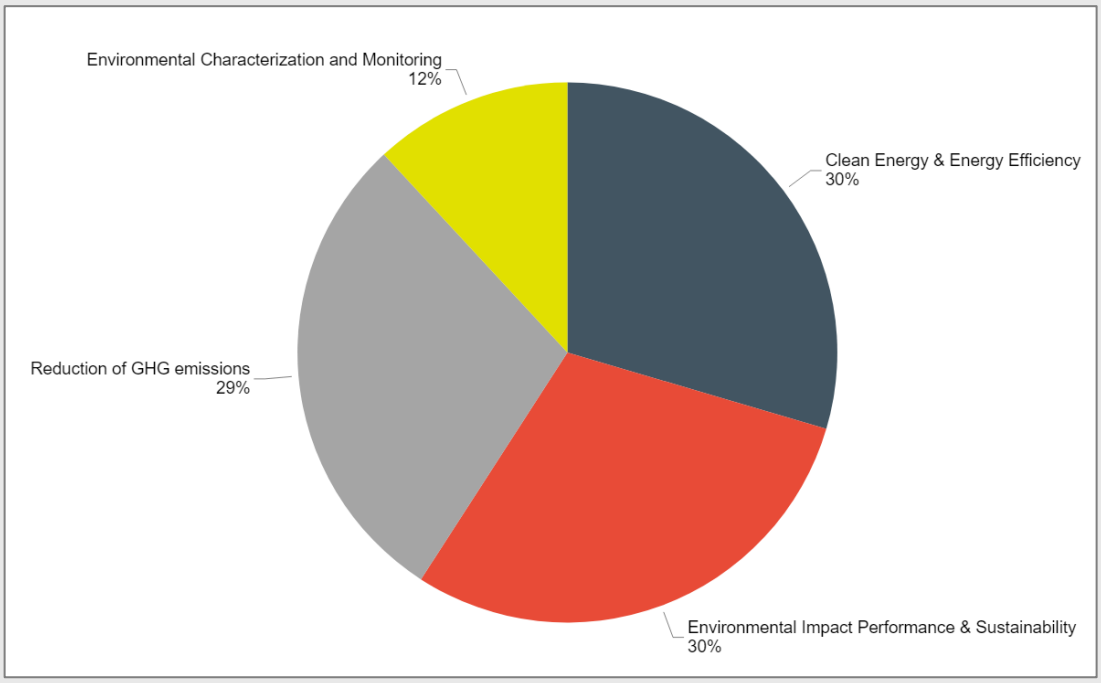


Figure A3-3: Secondary Cleantech Sub-sector Operations of Stakeholder Organizations

A.3.2 Private Sector Business Base Mapping

A.3.2.1 Overall Size & Location

In total 205 private sector organizations were found, employing at least 7,600 people between them. Similar analysis to the stakeholder organization was undertaken on these 205 private sector supply chain businesses.

A.3.2.2 Geographic Analysis

Private sector organizations were in four provinces, shown below:

Table A3-4: Number of Private Sector Organizations by Province

Province	Private Sector Organizations	% of Private Sector Cleantech Organizations
Nova Scotia	105	41%
Newfoundland and Labrador	101	40%
New Brunswick	39	15%
Prince Edward Island	5	2%
Not Known	5	2%

Source: Glass ai

A.3.2.3 General Sector Breakdown

Glass ai allocated each business to a standard sub-sector based on their web analysis which shows most private sector organizations operate within the oil and energy sub-sector followed by environmental services and conservation.

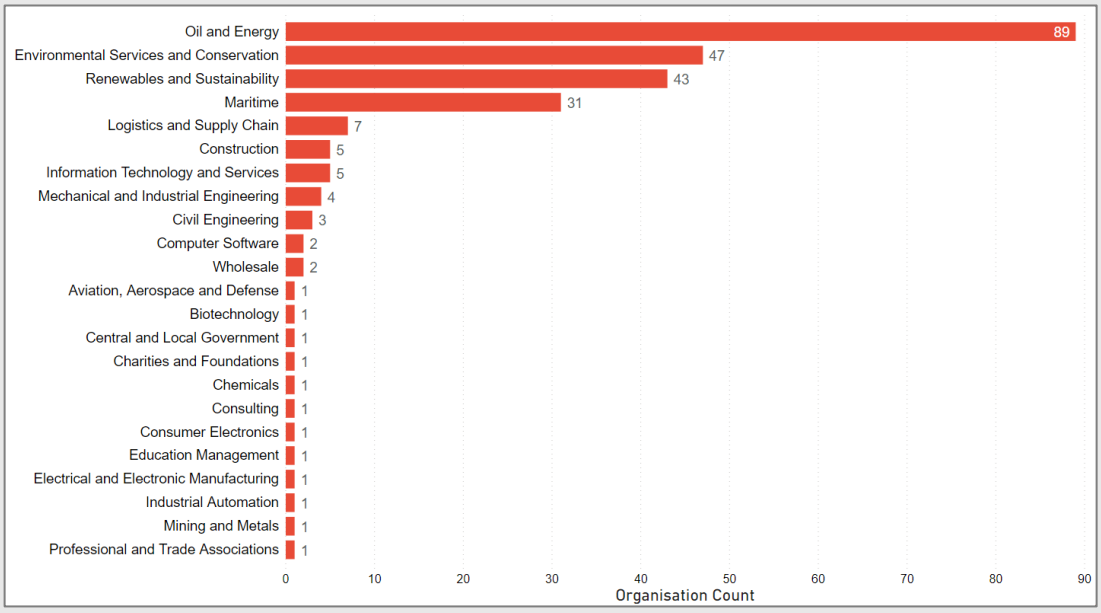


Figure A3-4: Number of Organizations by Standard Sub-sector

Within each of these sub-sectors the five largest organizations (where possible) are shown in the table below.

Table A3-5: Top 5 Largest Organizations for each Standard Sub-sector

Organizations	Employees
Aviation, Aerospace and Defense	
PAL Aerospace	320
Biotechnology	
eDNAtec	5
Central and Local Government	
Nova Scotia Department of Energy and Mines	0
Charities and Foundations	
Acadia Tidal Energy Institute	0
Chemicals	
Air Liquide Canada	0
Civil Engineering	
AECOM Canada	0
Strum Consulting	40
Tiller Engineering	12
Computer Software	
alooki technology	3
GRI Simulations	18
Construction	
Pennecon	383
Pennecon Energy Hydraulic Systems	384
Petro Service	31
RothLochston	113
Troy Life & Fire Safety	341
Consulting	
Envigour Policy Consulting	0
Consumer Electronics	
Seaformatics Systems	5
Education Management	
Keyin College	70
Electrical and Electronic Manufacturing	
Ocean Sonics	17
Environmental Services and Conservation	
ADI Systems, an Evoqua brand	34
Blue Water Group	27
Envirosystems	94
Fundy Engineering	26
JASCO Applied Sciences (Canada)	79
Industrial Automation	
Avalon Controls	10
Information Technology and Services	
Focus FS	9
RtTech Software	12

Organizations	Employees
SHIFT Energy	8
SimpTek Technologies	14
SmartICE	9
Logistics and Supply Chain	
PF Collins International Trade Solutions	70
Woodward Group of Companies	0
CTS Container & Trailer Services	0
Fleetway	0
Hunt's Logistics	0
Maritime	
Altera Infrastructure	484
Atlantic Towing	248
LOC Canada	596
McKeil Marine	191
QPS	390
Mechanical and Industrial Engineering	
EPCO Services	0
Mulgrave Machine Works	17
qualiTEAS	4
Trane Canada (East)	42
Mining and Metals	
MacGregors Industrial Group	27
Oil and Energy	
Axess Baffin	364
EM&I Group	115
NARL Refining Partnership	144
Offshore Technical Services	111
Vertex Resource Group	272
Professional and Trade Associations	
Ocean Technology Council of Nova Scotia (OTCNS)	0
Renewables and Sustainability	
DP Energy	27
Jaza Energy	21
Mara Renewables Corporation	31
One Wind	81
Terrapure Environmental	494
Wholesale	
Blue Water Agencies	53
Import Tool Corporation	0

A.3.2.4 Cleantech Sub-Sectors

The top 15 keywords found within the web presence of all private sector organizations are shown below. The figures simply show the number of times each keyword was mentioned on company's web presence.

Table A3-6: Top Keywords of Private Sector Organizations

Keyword	Number of Keyword Mentions on Private Sector Organizations' web presence
Efficiency	161
Sustainable	161
Innovation	160
Carbon	157
Wind	154
Climate	149
Waste	147
Climate Change	138
Solar	134
Sustainability131Ice	126
Greenhouse Gas	119
Pollution	115
Energy Efficiency	114
Real-Time	114
Environmental Impact	113
Wave	113

There is a broadly even split across the most commonly used keywords, with private sector organizations expressing. These keywords have been used to identify which cleantech sub-sectors the private sector businesses are operating in. Each business has been allocated to a principal cleantech sub-sector based, based on the frequency that they use relevant keywords relevant to each of the four sub-sectors.

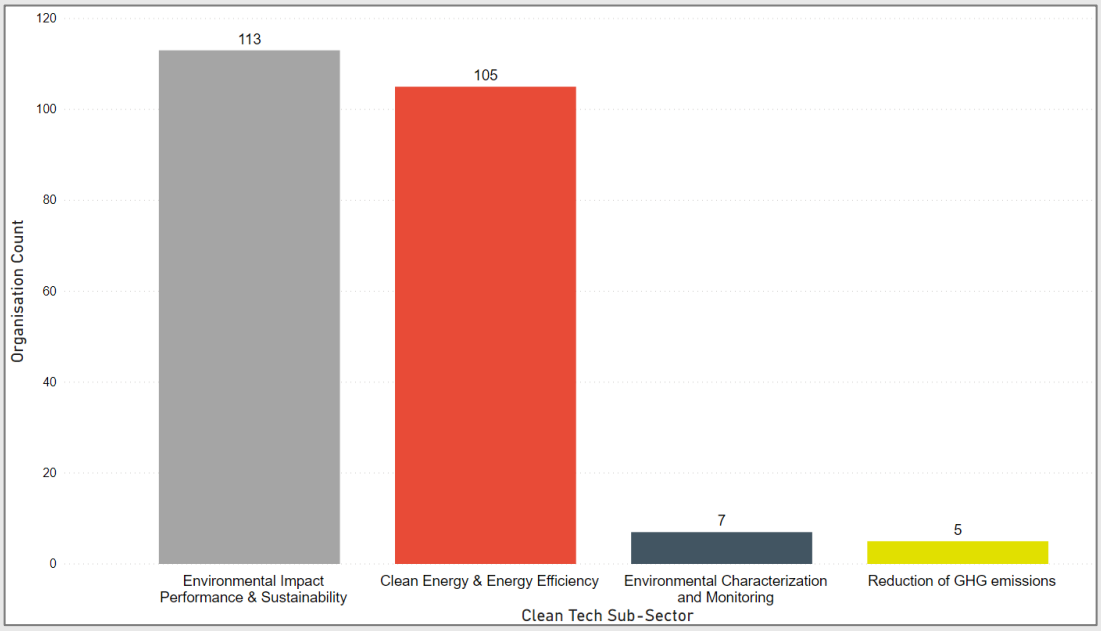


Figure A3-5: Principal Sub-sector Operations of Cleantech Private Sector Organizations

Nearly all (85%) of private sector companies (218 organizations) principally operate within one of two sectors: The Environmental Impact Performance & Sustainability and the Clean Energy & Energy Efficiency sectors. This is in line with the sub-sector split of stakeholder organizations (outlined above) where 97% of organizations operate in these two sectors. 25 private sector organizations could not be allocated a principal sub-sector due to lack of keywords found on the web presence of these organizations.

Most private sectors undertake activity relevant to one of the other cleantech sub-sectors beyond their principal sector. The analysis below illustrates the spread of activity among the private sectors businesses[1] The assessment shows that although there are few businesses whose principal sector is Reduction GHG emissions there is a base of other businesses that are engaging in this market area.

[1] Based on those sectors where they have a proportionate score count >25% of their total.

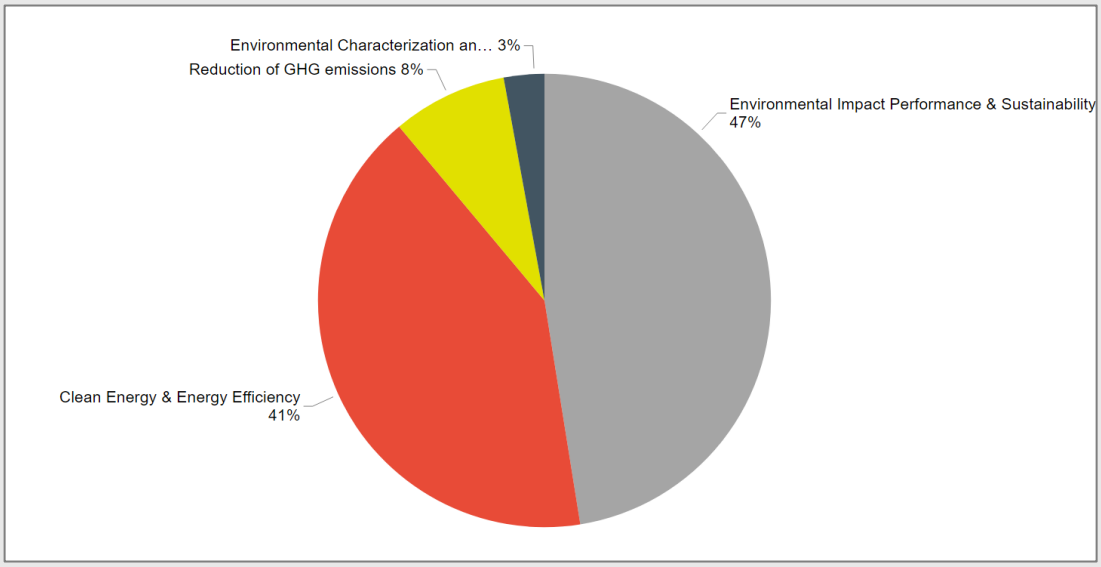


Figure A3-6: Secondary Sub-sector Operations of Cleantech Private Sector Organizations

A.3.2.5 Sub Sectors

A.3.2.5.1 Clean Energy & Energy Efficiency

Just over 40% (105) of the private sector organizations operate principally within this sub-sector and they employ at least 2,700 people. There are a further 67 companies that operate in this is market area (albeit as a secondary sector). Most of the companies operating principally in the Clean Energy & Energy Efficiency sub-sector are located in Nova Scotia (50). This is then followed by Newfoundland and Labrador, with 34 businesses, New Brunswick with 18 and Prince Edward Island with 2.

The top 15 keywords identified from organizations principally operating in this sub-sector are outlined here:

Table A3-7: Top 15 Keywords of Private Sector Organizations Operating Principally in Clean energy & Energy Efficiency Area

Keyword	Number of Keyword Mentions on Private Sector Organizations' Web Presence Operating Principally in the Clean Energy & Energy Efficiency
Efficiency	161
Innovation	160
Wind	154
Solar	134
Energy Efficiency	114
Wave	113
Clean Energy	109
Nuclear	108
Renewables	107
Biomass	100
Hydrogen	100
Wind Energy	97
Tidal	90
Wind Power	90
Energy Storage	81

A.3.2.5.2 Environmental Impact Performance & Sustainability

Just under half (113) of the private sector organizations operate principally within this sub-sector and they employ at least 4,000 people. A further 84 private sector companies appear to undertake a reasonable degree of activity in this cleantech sub-sector .

Most organizations operating principally in the Environmental Characterization and Monitoring sub-sector are located in Newfoundland and Labrador, 49 cleantech organizations. This is then followed by Nova Scotia, with 42 businesses and New Brunswick with 19. The top 15 keywords identified from organizations principally operating in this sub-sector are outlined here:

Top 15 Keywords of Private Sector Organizations Operating Principally in the environmental impact performance & sustainability sub-sector

Table A3-8: Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Environmental Impact Performance & Sustainability Area

Keyword	Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Environmental Impact Performance & Sustainability
Sustainable	161
Carbon	157
Waste	147
Sustainability	131
Pollution	115
Real-Time	114
Environmental Impact	113
Recycling	113
Subsea	103
Wastewater	92
Sustainable Energy	80
Environmental Monitoring	73
Remediation	70
Oil Spill	68
Biodiversity	67

A.3.2.5.3 Environmental Characterization and Monitoring

Just seven private sector companies operate principally within this sub-sector, making up only 3% of all private sector organizations and employing at least 49 people. A further five companies have been identified as operating partly in this sub-sector .

The principal operators in this sub-sector are split between Newfoundland and Labrador where five businesses are located with the remaining two in Nova Scotia. The keywords identified from organizations principally operating in this sub-sector are outlined here:

Keywords of Private Sector Organizations Operating Principally in the environmental characterization and monitoring sub-sector

Table A3-9: Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Environmental Characterization and Monitoring Area

Keyword	Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Environmental Characterization and Monitoring
Ice	126
Environmental Science	49
Iceberg	34
Environmental Technology	26
Sea States	17
Seabed Mapping	16
Environmental Characterization	5
Environmental Genomics	5
Environmental Sensing	5

A.3.2.5.4 Reduction of GHG Emissions

Just five private sector companies have been located that operate principally within this sub-sector, equating to 2% of all private sector organizations and accounting for just under 40 jobs. However, a further 29 private sector companies cite keywords related to this sub-sector at a sufficient rate for us to consider their operations as a relevant part of the sector.

The principal operators in this sub-sector are split between Newfoundland and Labrador where two businesses are located with the remaining three in Nova Scotia. The keywords identified from organizations principally operating in this sub-sector are outlined here:

Keywords of Private Sector Organizations Operating Principally in the reduction of GHG emissions sub-sector

Table A3-10: Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Reduction of GHG Emissions Area

Keyword	Number of Keyword Mentions on Private Sector Organizations' web presence Operating Principally in the Reduction of GHG Emissions
Climate	149
Climate Change	138
Greenhouse Gas	119
Carbon Dioxide	91
Carbon Emissions	89
Carbon Footprint	85
GHG	83
Global Warming	83
Low Carbon	83
Low-Carbon	73
Net Zero	59
Carbon Capture	47
Climate Action	44
Zero Carbon	44
Decarbonization	26

A.4 Survey Forms Design

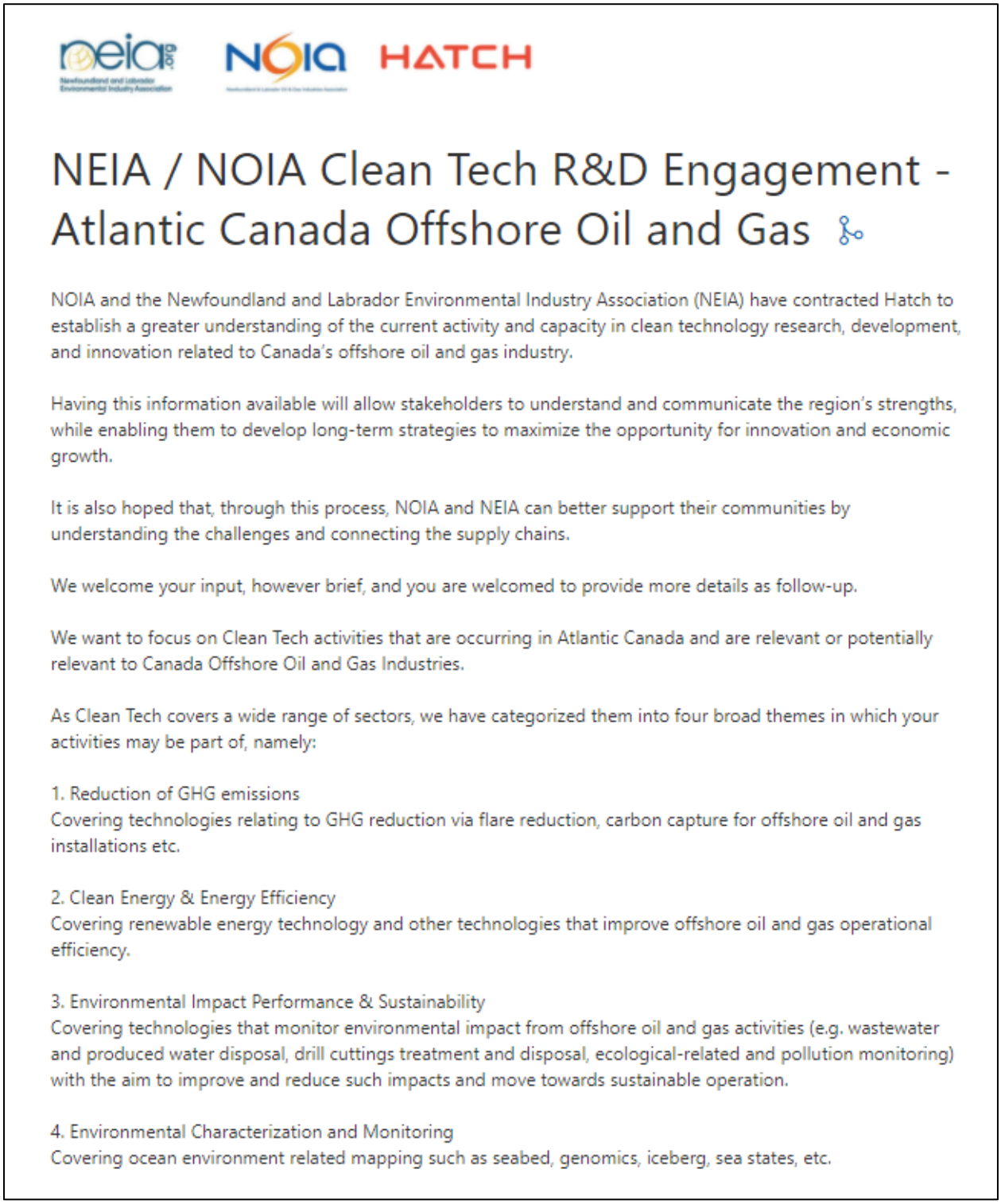
A different survey form was created to engage each of the following organization type:

1. Oil and Gas Operator
2. Tier-1 Contractors
3. Post-Secondary Institutions
4. Research Brokers/Agency
5. Private Sectors

A total of five distinct survey forms were created. A mixture of online survey and webchat interviews were used to engage different organizations. The forms were used to prompt the participant(s)/interviewee(s) during the interview, as guidance for the interviewer(s) or sent out for the relevant organizations to complete.

A webchat lasting no longer than an hour was the preferred engagement method when engaging the Oil and Gas Operator,Tier-1 Contractors, Post-Secondary Institutions, Incubators and R&D Facilitators. As the private sectors represented the biggest group, an online survey form was sent out to gather responses.

An introduction to the intent and the definition of cleantech was included in each survey and this is shown in Figure A4-1. Questions for each organization type are summarized in Table A4-1.



NEIA / NOIA Clean Tech R&D Engagement - Atlantic Canada Offshore Oil and Gas

NOIA and the Newfoundland and Labrador Environmental Industry Association (NEIA) have contracted Hatch to establish a greater understanding of the current activity and capacity in clean technology research, development, and innovation related to Canada's offshore oil and gas industry.

Having this information available will allow stakeholders to understand and communicate the region's strengths, while enabling them to develop long-term strategies to maximize the opportunity for innovation and economic growth.

It is also hoped that, through this process, NOIA and NEIA can better support their communities by understanding the challenges and connecting the supply chains.

We welcome your input, however brief, and you are welcomed to provide more details as follow-up.

We want to focus on Clean Tech activities that are occurring in Atlantic Canada and are relevant or potentially relevant to Canada Offshore Oil and Gas Industries.

As Clean Tech covers a wide range of sectors, we have categorized them into four broad themes in which your activities may be part of, namely:

1. Reduction of GHG emissions
Covering technologies relating to GHG reduction via flare reduction, carbon capture for offshore oil and gas installations etc.

2. Clean Energy & Energy Efficiency
Covering renewable energy technology and other technologies that improve offshore oil and gas operational efficiency.

3. Environmental Impact Performance & Sustainability
Covering technologies that monitor environmental impact from offshore oil and gas activities (e.g. wastewater and produced water disposal, drill cuttings treatment and disposal, ecological-related and pollution monitoring) with the aim to improve and reduce such impacts and move towards sustainable operation.

4. Environmental Characterization and Monitoring
Covering ocean environment related mapping such as seabed, genomics, iceberg, sea states, etc.

Figure A4-1: Survey Form Introduction

Table A4-1: Survey Form Questions

Organization	Questions
Oil and Gas Operator	1. What are the most urgent challenges in your industry relating to the four cleantech themes? 2. Please provide details for Top 5 cleantech projects you are currently investing in Atlantic Canada. 3. What percentage of your company's R&D investment is focused on cleantech in Atlantic Canada? (*Choices from 0-25%, 26-50%, 51-75%, >75%*) 4. What are the key drivers in your decision regarding cleantech spending in the Atlantic Canada? (*Choices from More Important, Neutral, Less Important or N/A for each of the following category: Access to Provincial/Federal Funding, Access to supply chain, Financial Viability, Regulatory Driver, Social Responsibility*)
Tier-1 Contractors	1. What are the most urgent challenges in your industry relating to the four cleantech themes? 2. What are your primary products and services relating to cleantech for the offshore oil and gas in Atlantic Canada? 3. Please provide details for Top 5 cleantech development you are currently investing in. 4. What percentage of your company's revenue is spent on cleantech R&D regionally? 5. What are the key drivers in your decision regarding cleantech engagement in the Atlantic Canada? (*Choices from More Important, Neutral, Less Important or N/A for each of the following category: Access to Provincial/Federal Funding, Access to supply chain, Financial Viability, Regulatory Driver, Social Responsibility, Demand*)
Post-Secondary Institutions	1. What are the primary fields of research undertaken at your institution in the cleantech field, relevant to the offshore oil and gas industry? 2. Where possible, please provide details on faculty, personnel, research topics, stage of development (TRL), funding, industry partners and facilities. 3. What post-secondary degree programs are being offered in the area of cleantech? 4. How much funding is being granted on cleantech R&D every year on average? 5. Please rank from highest to lowest your funding source on cleantech R&D! *(Oil and Gas Operator, Tier-1 Contractors, Federal/Provincial government, Private Sectors (outside Tier-1 Contractors)* 6. Please provide examples of cleantech from your institution that have been successfully commercialized in the offshore or related industries.
R&D Facilitators	1. What are the most urgent challenges in the offshore oil and gas industry relating to the four cleantech themes? 2. Please provide details for Top 5 cleantech projects you are currently investing in Atlantic Canada. 3. What percentage of your R&D activities is focused on cleantech in Atlantic Canada? (*Choices from 0-25%, 26-50%, 51-75%, >75%*) 4. What are the key drivers in your decision regarding cleantech R&D investment in the Atlantic Canada? (*Choices from More Important, Neutral, Less Important or N/A for each of the following category: Access to Provincial/Federal Funding, Access to supply chain, Financial Viability, Regulatory Driver, Social Responsibility*)

Organization	Questions
Private Sectors	1. What is your company's general view of investment in new cleantech solutions for the oil and gas market? 2. Are you currently investing in cleantech products and services relevant to the offshore oil and gas market? **For those currently investing in cleantech products and services relevant to the offshore oil and gas market:** a. In your own words, please describe the type of cleantech products and services your company currently supplies, particularly those that are relevant to the offshore oil and gas market. b. Which of these best describes your company's views on the market for clean teach solutions that you are currently operating in...(*Choose all that applies from: Proving very costly, Proving risky and complex, Going well and we expect to achieve our objectives and Going well and we are planning to scale-up our investment*) c. If you are developing new cleantech solutions in Atlantic Canada for offshore Oil and Gas application, please could you give us an outline of their scope and focus? d. Please could you provide us with a general sense of the scale of your company's investment in cleantech R&D globally as a proportion of revenue over the last 3 years. (*Choices from <1%, 1-3% 3-5%, 5-10%, 10-20%, >20%)* e. How much of the R&D mentioned above is taking place in Atlantic Canada? (*Choices from None, <10%, 10-25% 25-50%, 50-75%, 75-99%, 100%)* f. If you company has been engaged in cleantech plans to get involved, what have been the drivers for your company? (*Choices from Very Important, Important, Somewhat Important or Not Relevant for each of the following category: Access to Provincial/Federal Funding, Access to Technology, Customer Demand, Regulatory Driver, Long Term Strategic Commitment to Continuous Innovation and Sole initiative of an individual or individuals within the company*) **For those currently NOT investing in cleantech products and services relevant to the offshore oil and gas market:** a. We have not entered the market because... *(Choose all that applies from: The prospects are too risky, Its it too costly to explore, we believe the end market is too small relatively to the cost and complexity of developing solutions, this is already crowded marketplace and too competitive for us to want to enter, We have too little technical knowledge, We cannot see a gap in the market*) b. We would be interested in developing new cleantech solutions if... (*Choose all that applies from: We had help to understand how best to progress, Had access to more suitable investment funds*) c. If your company were to invest in clean teach, what would be the drivers for your company? (*Choices from Very Important, Important, Somewhat Important or Not Relevant for each of the following category: Access to Provincial/Federal Funding, Access to Technology, Customer Demand, Regulatory Driver, Long Term Strategic Commitment to Continuous Innovation and Sole initiative of an individual or individuals within the company*)

A.5 Glass ai Private Business Capability Mapping to Sector Challenges

Figure A5-1 shows the mapping of relevant keywords to each challenge in order to filter the private businesses for their capabilities in addressing sector challenges from Section 3.2. The private businesses shortlisted for each challenge were screened manually through high level web research before they were included as part of the relevant challenge supply chain ecosystem.

No.	Consolidated Keywords to map private businesses to sector challenges	Challenges Number in Report							
		1 Env Sensing, Monitoring and Characterization	2 Production Efficiency Optimization	3 Turbine Emissions Reduction & Electrification	4 Flaring Reduction and Recovery	5 Hazardous Offshore Discharges and Disposal	6 Oil Spill Emergency Response	7 Logistics Transportation Optimization	8 Remote and Integrated Operations
1	Advanced Materials			■			■	■	
2	Alternative Fuel			■					
6	Bioenergy			■					
7	Biofuel			■					
8	Biomass		■	■		■			
9	blue hydrogen			■					
10	booms						■		
11	Carbon capture		■	■	■			■	
12	Carbon emissions			■				■	
13	Carbon storage				■				
14	Carbon-neutral			■	■				
15	Clean energy			■					
16	Cogeneration		■					■	
17	combined cycle combustion		■					■	
18	dispersant						■		
19	dispersion						■		
20	Distributed Generation			■					
21	Drill mud					■			
22	Drillcutting					■			
23	Electric vehicle			■				■	
24	Electrification			■					
25	Energy efficiency		■						
26	Energy Management		■					■	
27	Energy storage			■				■	
28	Enhanced Oil Recovery (EOR)		■		■				
29	Flare Recovery				■				
30	Geothermal			■					
31	GHG			■					
32	Green chemistry			■				■	
33	Green energy			■					
34	Green transportation							■	
35	Green vehicle			■				■	
36	grey hydrogen							■	
37	Heat pump		■	■					
38	Hydroelectricity			■					
39	hydrogen			■					
40	Hydrokinetic			■				■	
41	Low carbon			■					
42	Low-carbon			■					
43	Microgeneration			■					
44	Microgrid			■				■	
45	Net zero			■					
46	Nuclear			■					
47	pilotless flaring				■				
48	Produced Water					■			
49	Recycling					■			
50	Remediation					■	■		
51	Renewables			■					
52	SDG		■	■		■			
53	skimmers						■		
54	Small Modular Reactor			■					
55	Smart city							■	
56	Smart energy							■	
57	Smart grid			■				■	
58	Solar			■				■	
59	Solar energy			■				■	

No.	Consolidated Keywords to map private businesses to sector challenges	Challenges Number in Report							
		1 Env Sensing, Monitoring and Characterization	2 Production Efficiency Optimization	3 Turbine Emissions Reduction & Electrification	4 Flaring Reduction and Recovery	5 Hazardous Offshore Discharges and Disposal	6 Oil Spill Emergency Response	7 Logistics Transportation Optimization	8 Remote and Integrated Operations
60	Solar photovoltaics			■				■	
61	Super grids			■				■	
62	Sustainable Development Goals		■	■		■			
63	Sustainable energy		■	■		■			
64	Sustainable engineering		■	■		■			
65	Tidal			■				■	
66	value from waste			■		■			
67	Waste					■			
68	Wastewater					■			
69	wastewater					■			
70	Wave			■				■	
71	Wind			■				■	
72	Wind energy			■				■	
73	Wind power			■				■	
74	anthropogenic noise	■							
75	biodiversity	■							
76	Characterization and monitoring	■							
77	edna	■							
78	Emission Monitoring	■				■			
79	Environmental Impact	■							
80	environmental characterization	■							
81	environmental effects	■							
82	environmental genomics	■							
83	environmental monitoring	■							
84	Environmental science	■							
85	environmental sensing	■							
86	Environmental technology	■							
87	ice	■							
88	iceberg	■							
89	Leak Detection and Repair (LDAR)	■					■		
90	oil spill	■					■		
91	Oil Spill Detection	■					■		
92	Oil Spill management	■					■		
93	oil spill response	■					■		
94	Pollution	■							
95	real-time	■							
96	sea states	■							
97	seabed mapping	■							
98	seabed sampling	■					■		
99	seabirds	■							
100	whales	■							
101	Risk mitigation	■							
102	subsea	■					■		
103	Zero plastic	■				■			
104	Remote		■					■	■
105	battery			■					■
106	Predictive analytics		■					■	■
107	Scheduling							■	
108	Logistics							■	
109	Transportation							■	
110	Marine Vessels							■	
111	CCS		■	■	■			■	
112	Digitalization	■	■	■	■	■	■	■	■
113	Drone	■	■						■
114	Robotics	■	■						■
115	Artificial Intelligence	■	■				■	■	■
116	Digital Twin	■	■			■	■	■	■
117	Simulator	■	■				■	■	■

Figure A5-1: Mapping of Capabilities Keywords to Sector Challenge

HATCH